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INVESTIGATION ON THE ACTION OF THE TROPICAL SUN ON MEN AND ANIMALS.

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The meteorologic conditions which surround us, such as temperature, humidity, barometric pressure and the movements in the atmosphere, all of which, to a great extent, are controlled by the radiation of the sun, are included under the designation of climate. Each of these factors of environment has its characteristic influence upon the life functions of living organisms. We can, on the one hand, study the influence of differing temperatures, humidities, and movements and pressures of the air on men and animals in modern respiration calorimeters without the need of conducting the work in a particular climate. Rubner,[1] especially, has carried on such work. But, on the other hand, the action of the sun of a given latitude can not be reproduced artificially.

The radiant energy of the sun which reaches the atmosphere is in part absorbed while passing through the latter, and this absorption, other conditions being equal, should be smaller the less deep the absorbing layer. If conditions, such as layers of the atmosphere of unequal density which would tend to refract the rays, do not intervenc, and again, if all other conditions are equal, the absorption is smallest during the vertical incidence of the rays; that is, when the sun is in the zenith.

[1] *Arch. f. Hyg.* (1894), **20**, 309–312, 345–364, 365–371; (1895), **23**, 87, 13–43; (1900), **38**, 120–159. Die Gesetze des Energieverbrauches bei der Ernährung, Leipzig-Wien (1902).

Because of the more nearly vertical incidence of the sun's rays in the Tropics, a greater proportion reaches the earth and with a greater intensity on a given area than in the northern and southern latitudes. Of course, in granting this, such phenomena as cloud formation are excluded.

The tropical sunlight, in so far as the violet and ultra-violet end of the spectrum is concerned, has been studied extensively in the past few years in the Bureau of Science in Manila by Freer,[2] Gibbs,[3] and Bacon,[4] and the effects produced by this portion of the sunlight have been and are being compared with those obtainable by observers using the same means of measurement in other latitudes. These investigations up to the present have shown that the spectrum of the sun's rays does not extend much, if any, farther into the ultra-violet in Manila than in northern climates. Observations carried on daily during the year on the decomposition of a solution of oxalic acid under the influence of uranyl acetate as a catalyzer[5] have shown as great variations between individual days, even of the same apparent brightness, and some decomposition even on cloudy and rainy days; however, with a general tendency toward maximum decomposition when the sun is nearest the zenith and of minimum under opposite conditions. The comparative measurements in other countries are not as yet available to any extent, with one exception. Bacon showed that the decomposition in Manila in July was from five to twenty times greater than in Chicago in June.

The work with the ultra-violet spectrum was of interest not only because it is necessary thoroughly to consider these rays in a study of tropical sunlight, but also because of the number of authors,[6] especially in modern times, who are inclined to the belief that the action of the tropical sun on the human organism is to be attributed to the influence of the rays of shorter wave length. As a result of this belief a special underwear, which by its color should be impermeable to the ultra-violet rays, has recently been recommended for use in the Tropics.

An extensive investigation of the relation of the color of underwear to the health of men in this climate was made by Phalen and Nichols[7]

[2] *This Journal, Sec. B* (1910), **5**, 1.

[3] *Ibid., Sec. A* (1909), **4**, 133; (1910), **5**, 9 and 419.

[4] *Ibid.* (1910), **5**, 267.

[5] The solution of oxalic acid uranyl acetate is only acted upon by the ultra-violet end of the spectrum. The results of this work will be published later from the Bureau of Science.

[6] Woodruff, C. E., The Effects of Tropical Light on White Men. New York and London, (1905); Duncan, *Journ. Roy. Army Med. Corps* (1908), **11**, 71; Simpson, *Ibid.*, 441–449; Gihon, Twentieth Century Practice of Medicine, New York (1895), **3**, 253–285.

[7] *This Journal, Sec. B* (1911), **6**, 525.

on 1,000 American soldiers in the Philippines. The results, as to the advantage of orange-red, were negative. This fact, when considered in connection with a number of observations which I have made during my stay in the Tropics, convinced me that the rays of the tropical sun having greater wave length, that is, those in the red and ultra-red end of the spectrum, play the most important rôle in producing the untoward effects generally attributed to tropical sunlight.

In making this statement it must be understood that it refers to organisms having the capability of regulating the body heat, and not to those low in the scale, such as bacteria or protozoa, for it has been shown repeatedly [8] that in the case of the latter ultra-violet rays exert a most destructive action, heat coming into consideration only in so far as such organisms are not able to live when the temperature is above a certain point. Plants also, the normal life action of which depends on the chlorophyll, of course are markedly affected by the ultra-violet as well as by the other end of the spectrum.

In order correctly to interpret the experiments given in subsequent portions of this paper, it will be necessary briefly to review the physiologic processes concerned in heat regulation in the bodies of mammalia.

The body possesses the capability not only of regulating its heat production from the combustion of foodstuffs (chemical heat regulation), but also its loss of heat from convection, radiation and water evaporation (physical heat regulation). Normally, the thermal effects of the surroundings are compensated either by a suitable transference of heat to the surroundings, or by the conservation or production of heat within the body, so that the body temperature within narrow limits remains practically the same. However, there are limits to the power of regulation. If the body is heated too intensively or the loss of heat is inhibited, the latter will accumulate and the body temperature rise.

The higher the temperature of the surroundings, the less will be the loss of heat by conduction or radiation, and if this temperature exceeds that of the body, no heat can be lost in this way, but on the contrary the balance is changed, and the energy lost to the body would now be accumulated in it were it not for the loss occasioned by the evaporation of water from the lungs and the surface of the body.

High air temperatures alone do not change the body temperature as long as the latter can be regulated by the loss of sufficient heat through water evaporation.[9] Therefore, a man can withstand temperatures even of 129° for a considerable time if the air is comparatively free from water vapor. On the other hand, if the relative humidity is high and,

[8] *Loc. cit.*

[9] Hill, Leonard, Recent Advances in Physiology and Biochemistry, London, (1908), 256–274.

therefore, the evaporation of water from the body lessened, the loss of heat is inhibited.[10] It will be recalled that in many localities in America or Africa the thermometer in summer often is much higher than it is in the Tropics, yet the heat by no means produces the same effect. The humidity in the Tropics is always comparatively high, because the air for considerable periods of time is nearly saturated with water vapor. It might be stated that it is not regions of high air temperatures, but those having a high relative humidity which produce especially untoward effects by reason of their climate.[11] However, if the air is in motion, even if it is very humid and hot, increased water evaporation and conduction bring about a great loss of heat. This fact is of great importance in the Tropics. The fresh winds prevalent here render the climate of Manila in the months of May to August much more tolerable to human beings than is the case in certain parts of the Chinese coast or even on the Atlantic seaboard which lie considerably farther to the north.

Generally speaking, the majority of people living in the Tropics are on the coastal or intermontane plains, where the climatic conditions are nearly alike throughout the year. The high air temperatures and high relative humidity are maintained so that conditions retarding the loss of body heat are practically continuous, in distinction from those regions where, despite the fact that at certain times the heat and relative humidity are high, nevertheless the average for the year is low. However, the body temperature of man and probably also of animals, in spite of this fact, normally does not exceed the physiologic limits. This has been shown by a large number of careful measurements of body temperatures of white and colored men in the Tropics, and of the same people in the Tropics and in temperate climates. Variations, when they have been observed, are doubtless not greater than the daily ones encountered in other climates.

Finally, the radiation from the sun is obviously an important factor. Any object exposed to the sun's rays absorbs a portion of them. The majority of substances, and among them is included the animal body, have a much higher coefficient of absorption for heat than has the air, and therefore they become hotter in the sun than does the surrounding air. This effect of the heat radiated from the sun, while generally most intense in the Tropics, is present in all latitudes. Rubner, Cramer,[12] and Wolpert[12] have studied the results of insolation in temperate climates. According to their experience we can calculate approximately

[10] Haldane, *Journ. Hyg.*, Cambridge (1905), 5, 494.

[11] Of course it must be recalled that in the Tropics, where the relative humidity is high, the sun is often obscured by clouds.

[12] *Arch. f. Hyg.* (1894), 20, 313–344; (1892), 33, 206–228; (1902), 44, 322–338.

the temperature which corresponds to the thermic effect of the sun by adding half the number of degrees difference between the register of the black-bulb thermometer in the sun and the shade thermometer to the shade temperature. Applying this calculation to the conditions in the direct sunlight at Manila or other tropical place, for instance, Colombo, we find that this temperature is considerably above the one normal for the body.

The pyrheliometer devised by Angstrom [13] alone seems capable of measuring exactly the caloric value of the radiation of the sun. This instrument has been adopted by an international meteorologic conference in Innsbruck. Measurements with it have been made in other parts of the world, but as yet no work has been done with it in the Tropics. The Rev. José Algue, S. J., Director of the Weather Bureau in Manila, has begun such investigations in connection with our experiments. However, an important part of his apparatus was broken, so that after repairs on it had been completed here, we could obtain only relative values for the different days. A new apparatus has been ordered and the figures after its arrival will be recalculated into absolute values.[14]

Therefore, we will shortly be in a position to furnish exact values for Manila and other places in the Philippines obtained by the pyrheliometer. It seems urgent that comparative studies in other parts of the world, especially tropical and subtropical regions, be made with the standard instrument of Angstrom. P. Schmidt estimates the heat effect of the tropical sun as being equal to 2 gram calories per square centimeter per minute.

I have found in the literature only a few observations concerning the action of the tropical sun on animals.

Scaghosi [15] exposed rabbits to the sun in Sicily. Their temperatures rose markedly, and upon continuing the experiment for a sufficient length of time, the animals died. Recovery took place if the direct insolation was stopped in sufficient time. Castellani and Chalmers [16] report some experiments which they performed in Colombo. They exposed rabbits with their heads shaved to the noon sun. The animals died in about sixty-seven minutes with all the symptoms and post-mortem appearances of sunstroke. Another rabbit, similarly treated, but protected by a red glass, lived. These authors concluded that sunlight can bring about "(1) sudden death, (2) congestion of the meninges of the brain. The ultra-violet rays seemed to have no effect and it would appear as if the active rays were in the visible violet." Of course the red glass also absorbed a very large proportion of the heat rays.

[13] *Astrophys. Journ.* (1899), **9**, 332.

[14] My thanks are due to the Rev. José Algue and to the Rev. Juan Comellas for the valuable assistance they have rendered, not only by the loan of apparatus and by conducting measurements, but also for advice on meteorologic subjects.

[15] Castellani and Chalmers, Manual of Tropical Medicine, London (1910), 86.

[16] *Ibid.*

Schilling[17] mentions a few experiments on rabbits: A thermometer under the skin of a white rabbit in the shade showed 38°.4. The animal was transferred into the sun (air temperature about 26°, black-bulb thermometer 46°.7). After half an hour the thermometer under the skin showed 40°.4. The skin was shaved, whereupon after half an hour the thermometer rose to 41°.5. The shaved skin was covered with a piece of black cotton cloth and within twenty-five minutes the temperature rose to 42°.8, the black cloth was removed and the thermometer fell to 39°.6, finally the same place on the skin was blackened with carbon, and within ten minutes the temperature rose to 42°.4. P. Schmidt[18] also exposed rabbits to the sun, but in a temperate climate, and observed in a white rabbit that the temperature *in ano* rose from 38°.5 to 39°.5 and from 38°.5 to 40°.2 in a black rabbit. The increase in temperature during one hour was only 0°.3 if the neck alone was exposed to the sun.

EXPERIMENTAL.

If the body of a dead dog or rabbit is placed in the sun of Manila, the temperature of the outer portion of the body, measured by introducing a thermometer under the skin, rapidly rises to 45° and more, thus exceeding the temperature of the surroundings. The absorbed heat will finally also warm up the deeper parts of the body, and therefore a thermometer placed in the rectum will rise. The figures obtained by experiments on dead animals are shown in Table I.

TABLE I.—*Rise in temperature of the bodies of dead animals exposed to the sun in Manila.*

Date.	Remarks.	Time.	Temperature. In ano.	Temperature. Under the skin.	Black-bulb thermometer.	Mercury thermometer in sun.
1910.			°C.	°C.		°C
Sept. 22	Dead rabbit placed on a board in sun at 8 a. m.	10.00 a. m.		43.0	53°.1 at 11 a. m.	
		11.00 a. m.		46.2		
Oct. 5	Brown dog, hung in sun on a vertical stick at 2 p. m.	2.30 p. m.	36.0	40.0	51°.4 at 2 p. m.	32.0
		3.00 p. m.	36.1	45.3		32.1
		3.30 p. m.	36.3	47.0		32.1
		4.00 p. m.	37.7	47.2		30.7

Of course, the body of a living animal exposed to the sun absorbs heat just as does that of a dead one, and so its temperature would rise in a similar manner were it not able to lose heat more rapidly by reason of its capacity for physical heat regulation.

A dog placed in the sun very soon exhibits the symptoms known as heat-hyperpnœa. Its respiration becomes quicker and forced, the tongue hangs from the mouth and saliva increases and drops from it. As

[17] *Arch. f. Schiffs.-u. Trop.-Hyg.* (1909), **13**, 1.

[18] *Arch. f. Hyg.* (1903), **47**, 262–290; (1908), **65**, 17–31; (1909), **65**, 1–20; *Arch. f. Schiffs.-u. Trop.-Hyg.* (1901), **5**, 207–233; 245–271.

dogs have no sweat glands, the evaporation of water, which in men is brought about by the secretion of sweat, is replaced in these animals by increased evaporation from the surfaces of the lungs, mouth, and especially the tongue.

However, in spite of the increased water evaporation, the body temperature measured *in ano* of the dog in the direct rays of the sun for several hours may rise 0°.5 to 1°. If the temperature is measured by inserting a thermometer or a thermopile into the subcutaneous tissues through a small incision of the skin, the subcutaneous temperature is found to be above 40°.

In a number of experiments, two comparable rabbits in each instance were kept side by side a few paces apart, one in the shade of a house or a wooden wall, the other exposed to the sun. The animals in the sun died in from one to three hours, the temperature *in ano* rising to febrile heights, the subcutaneous temperature in the sun increasing considerably above that simultaneously taken *in recto*. The animals in the shade behaved normally, their temperatures increasing but slightly.

TABLE II.—*Temperature, subcutaneous and rectal, of rabbits in the sun and shade.*

Date.	Remarks.	Time.	Temperature of rabbit in sun. Subcutaneous.	Temperature of rabbit in sun. Rectal.	Temperature of rabbit in shade. Subcutaneous.	Temperature of rabbit in shade. Rectal.	Temperature air in shade.	Black-bulb thermometer.
			°C.	°C.	°C.	°C.	°C.	
		7.55 a. m.	36.8	37.5	36.4	37.6	--------	42° at 11 a. m.
		8.15 a. m.	37.8	37.3	36.5	37.4	27.4	
1910.		8.30 a. m.	38.3	37.3	36.5	37.5	27.5	
Oct. 12	Two white rabbits.	8.45 a. m.	39.1	37.8	36.8	37.4	29.6	
	In animal house.	9.00 a. m.	39.2	38.8	36.8	37.5	30.0	
	Exposed 8 a. m.	9.15 a. m.	39.8	39.0	36.8	37.6	29.4	
		9.30 a. m.	40.8	39.2	37.9	37.9	30.7	
		9.45 a. m.	41.9	40.6	38.0	38.0	30.5	
		9.50 a. m.	Experiment discontinued, animals taken in.					
Oct. 18	Two brown rabbits.	8.20 a. m.	36.5	38.0	36.4	37.7	--------	54° at 11 a. m.
	In animal house.	8.50 a. m.	40.7	39.0	36.5	37.5	--------	
	Exposed 8.25 a.m.	9.20 a. m.	44.5	42.3	37.6	37.8	--------	
		9.50 a. m.	Animal dead.		37.9	38.1	--------	

Under the climatic conditions surrounding our experiments the number of calories lost depends mainly on the amount of water evaporated in a given time. A dog, by its peculiar hyperpnœa can evaporate relatively more water, and thus lose more heat than the rabbit. However, if we tracheotomize the animal this evaporation is inhibited. The expired air escapes through the tracheal cannula, so that the water vapor carried with the current can not reach the surface of the tongue, and therefore there is but a limited surface from which it can be evaporated.

In the shade, or inside of a room, a tracheotomized dog, while limited in its power of losing heat, shows a body temperature not above normal, but if such an animal is brought into the direct rays of the sun, the hyperpnœa appears just as with a normal dog but without so great an evaporation of water. Under these conditions the rectal temperature rises to febrile heights. If the experiment is continued for a longer time, the animal finally falls and dies, the respiration having markedly increased, the pulse greatly quickened, cyanosis of the mucous membrane having set in, saliva dropping from the mouth and secretion even having set in from the mucous membrane of the nose. In fact, the animal shows all the symptoms of heat stroke. I have several times interrupted the experiment before this last stage was reached. Then, if the temperature was not too high, it was possible to save the animals. The animals died in two experiments; one, after a few minutes, the other after several hours in spite of careful treatment with cool water. During this time the animal exhibited signs of disturbed orientation; it ran restlessly around, knocked its head against the wall, fell and jumped up again. These severe disturbances of the nervous system correspond to certain observations made during heat stroke in man. The conditions described above are made clear by Table III.

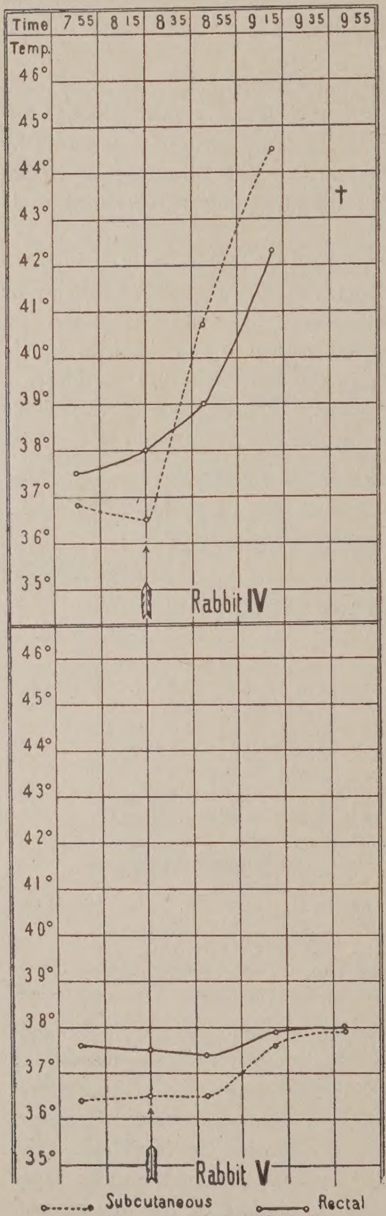


CHART I.

TABLE III.—*Temperature, subcutaneous and rectal of dogs in sun and shade.*

Date.	Remarks.	Time.	Temperature. Rectal.	Temperature. Subcutaneous.	Black-bulb thermometer.
			°C.	°C.	
		9.00 a. m.	36.9	----------	52°.1 at 11 a. m.
1910.		9.30 a. m.	37.8	----------	
Oct. 5	Brown dog, tracheotomized Oct. 4, 1910. In animal house. Exposed to sun 9.20 a. m.	9.40 a. m.	39.2	----------	
		9.50 a. m.	40.1	----------	
		9.55 a. m.	40.9	44.2	
		10.00 a. m.	41.0	----------	
		10.05 a. m.	42.0	45.5	
	Falls down in lethal condition, taken into room, died 10.40 a. m. (Rectal temperature 41°.)				
Oct. 19	Black dog, tracheotomized Oct. 17, 1910. In animal house. Exposed to sun 9.25 a. m.	9.00 a. m.	38.3	38.0	49° at 11 a. m.
		9.55 a. m.	40.7	42.9	
	Falls down at 10.10 a. m.; taken into room until 10.30 a. m.; exposed to sun again. Taken into room at 11.15 a. m.; recovers.	10.10 a. m.	41.7	42.9	
		11.00 a. m.	41.9	42.5	
		11.15 a. m.	42.8	37.9	
		12.30 p. m.	38.0	37.5	
Oct. 21	Same dog from Oct. 18, 1910. In animal house. Exposed to sun 8.45 a. m.	8.30 a. m.	38.0	37.0	45°.6 at 11 a. m.
		9.15 a. m.	40.0	41.0	
		9.50 a. m.	44.2	44.5 died.	

Tracheotomized rabbits, while inside of a room, act normally, but if they are exposed to the sun they die, the body temperature rising more rapidly than with normal rabbits.

The post-mortem findings in the dogs and rabbits which died were: Hyperæmia and a certain number of small hæmorrhages in the subcutaneous tissues, hyperæmia of all internal organs, especially of the brain and the meninges. Several punctiform and linear hæmorrhages could be seen on the surface of the brain, as well as on the dura mater.

I have attempted roughly to estimate from the loss in weight the relative quantities of water evaporated by rabbits in the sun and in the shade. I collected the fæces, urine, and saliva excreted and deducted this amount from the loss in weight of the animal. Of course, the figures obtained in this way are not exact, the carbon dioxide excretion not being taken into consideration, but a comparison between two animals otherwise under the same conditions gives an approximate idea of the loss of water. The calculations are given in Table IV.

TABLE IV.—*Loss of weight of rabbits in sun and shade.*

Time.	Total number of hours.	In sun.					In shade.				
		Weight.			Urine and fæces collected.	Reduced loss of weight.	Weight.			Urine and fæces collected.	Reduced loss of weight.
		At start.	At end.	Loss.			At start.	At end.	Loss.		
	h. m.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
8 to 9.50 a. m.	1 50	1,640	1,580	60	18	42	1,943	1,936	7	-------	7
2 to 4 p. m.	2 0	1,795	1,744	51	10	41	2,148	2,137	11	-------	11
9.30 to 11.45 a.m.	2 15	2,182	2,032	150	35	115	1,730	1,725	5	-------	5

Reduced per hour and kilo body weight.

Loss in sun.	Simultaneous loss in shade.
Grams.	*Grams.*
14	2
12	3
23	2

Cats behave more or less as do dogs or rabbits. Their body temperature rises, and if they are exposed to the tropical sun long enough, they will die.

EXPERIMENTS ON MONKEYS.

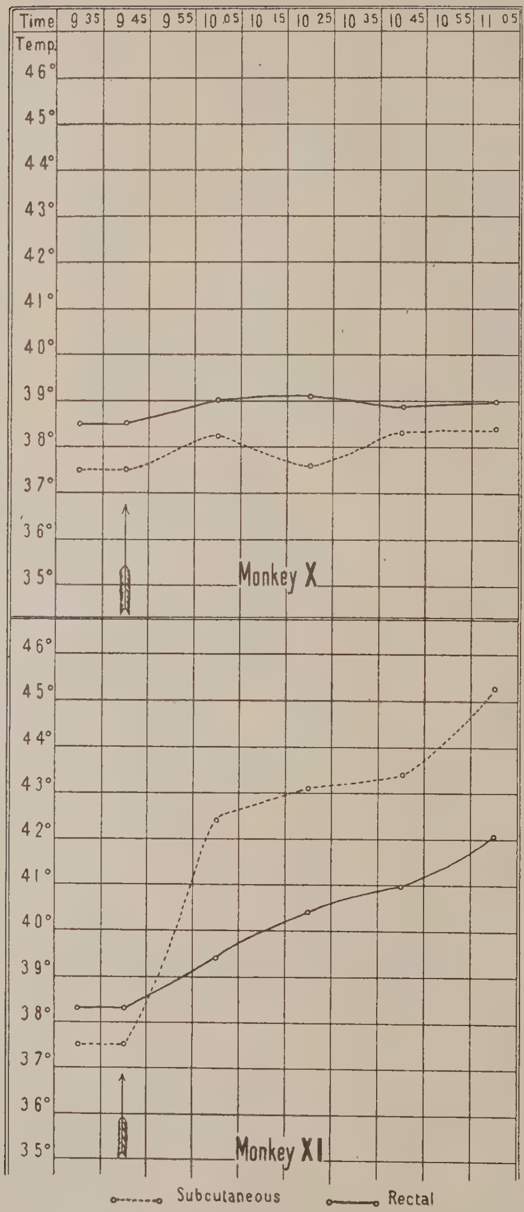
Experiments on monkeys promised the best result because these animals are at home in the Tropics. Monkeys, like rabbits and dogs, have no sweat glands, and their physical heat regulation is confined to the reduction brought about by water evaporated from the lungs and mouth by increased respiration. However, this capability to evaporate water is very limited. In my experiments the monkeys were fastened in sunny places in the garden, or on the roof to a small stick by means of a chain around their bodies. The body temperature of the animals exposed to the sun rose within one hour from 38°.5 or 39° to 42° or more. The subcutaneous temperature at the same time reached values of 45° and even 46°. Within seventy to eighty minutes the monkeys died, even if they were exposed to the sun in the early forenoon, between 9 and 10, in December and January. These months are among the coolest in Manila. Even an open umbrella gives sufficient shade to protect the animals from the injurious effects of the sun. I have especially studied the changes of the subcutaneous and rectal temperatures in monkeys and the relation between these two values deserves attention. The subcutaneous temperature in a normal monkey inside the house and for the greater part in the shade is somewhat below the rectal. As soon as the animals are placed in the sun, the subcutaneous temperature rises above the rectal, and, until the end of the experiment, exceeds the latter. The interior of the body is warmest in normal animals and becomes

cooler toward the periphery. In the sun, on the contrary, the body is hottest on the outside and cooler toward the inside, the latter now receiving heat from the periphery. As a result of this condition the temperature measured *in ano* in a normal animal is very nearly the same as that of the blood and surrounding tissues, but in monkeys exposed to the sun, it will lie, in all probability, below that point. The parts of the body nearest the periphery will show a temperature almost the same as the subcutaneous, the more central portions a temperature between the rectal and subcutaneous. Experiments may be mentioned in this connection in which two monkeys were exposed to the sun, the one with its normal coat of hair, the other, shaved all over. The temperature of the shaved animal rose much more rapidly than that of the other. On the other hand, in the shade or inside a house, the shaved animal has a slightly lower body, and a decidedly lower subcutaneous temperature. The explanation is clear when we consider the fact that the coat of hair protects both against loss of heat by conduction and an increase from radiation.

The following characteristic examples of protocols illustrate these points and they are even more plainly brought out by the temperature charts.

TABLE V.—*Experiments with normal and shaved monkeys.*

Date.	Remarks.	Time.	Temperature of— Monkey II exposed to sun. Subcutaneous	Monkey II exposed to sun. Rectal.	Monkey X in shade of umbrella. Subcutaneous	Monkey X in shade of umbrella. Rectal.	Monkey XI in normal hair coat exposed to sun. Subcutaneous	Monkey XI in normal hair coat exposed to sun. Rectal.	Monkey XII, shaved, exposed to sun. Subcutaneous	Monkey XII, shaved, exposed to sun. Rectal.	Black-bulb thermometer.
			°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	
1910.		8.50 a.m.	38.1	38.0	------	------	------	------	------	------	52°
Nov. 16	In animal	9.15 a.m.	39.8	42.0	------	------	------	------	------	------	------
	house.	9.30 a.m.	41.0	44.0	------	------	------	------	------	------	------
	Exposed to	9.45 a.m.	42.0	44.0	------	------	------	------	------	------	------
	sun 9 a.m.	10.00 a.m.	43.9	44.8	------	------	------	------	------	------	------
		10.08 a.m.	43.9	------	------	------	------	------	------	------	------
	Slight cramps, forced and slow respiration, saliva dropping, 10.10 a. m. died.										
		2.05 p.m.	------	------	37.5	38.5	38.1	38.4	36.6	37.9	------
1911.		2.35 p.m.	------	------	39.2	39.4	40.4	39.9	40.9	------	------
Jan. 18	In animal	2.40 p.m.	------	------	------	------	------	------	------	40.6	------
	house.	2.55 p.m.	------	------	------	------	------	------	44.6	43.8	------
	Exposed to	2.60 p.m.	------	------	------	------	43.2	41.4	44.8	44.0	------
	sun 2.25	3.05 p.m.	------	------	39.6	39.8	------	------	45.5	44.4	------
	p.m.	3.10 p.m.	------	------	------	------	43.8	41.4	------	Died.	------
		3.20 p.m.	------	------	------	------	------	41.6	------	------	------
		3.35 p.m.	------	------	40.3	------	44.4	------	------	------	------
		3.45 p.m.	------	------	------	------	------	42.3	------	------	------
		3.50 p.m.	------	------	40.2	40.5	------	------	------	------	------
		4.00 p.m.	------	------	------	------	44.5	43.4	------	------	------
		4.15 p.m.	------	------	40.0	40.1	45.4	44.1 died.	------	------	------


Time
9 35
9 45
9 55
10 05
10 15
10 25
10 35
10 45
10 55
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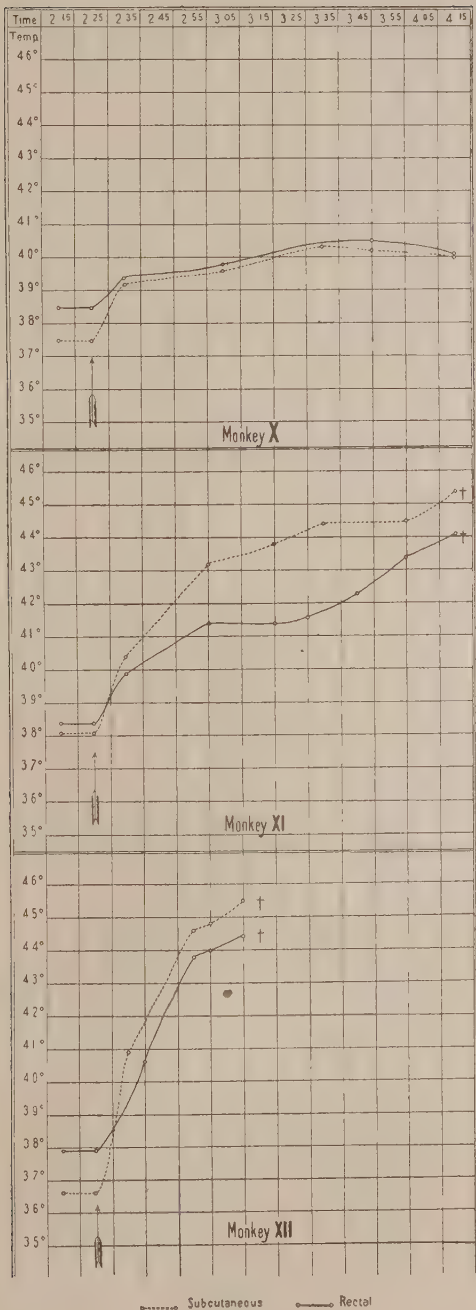
Temp.
46°
45°
44°
43°
42°
41°
40°
39°
38°
37°
36°
35°
Monkey X
Monkey XI
Subcutaneous
Rectal

CHART II.



Time
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38°
37°
36°
35°
Monkey X
Monkey XI
Monkey XII
†
Subcutaneous
Rectal

CHART III.

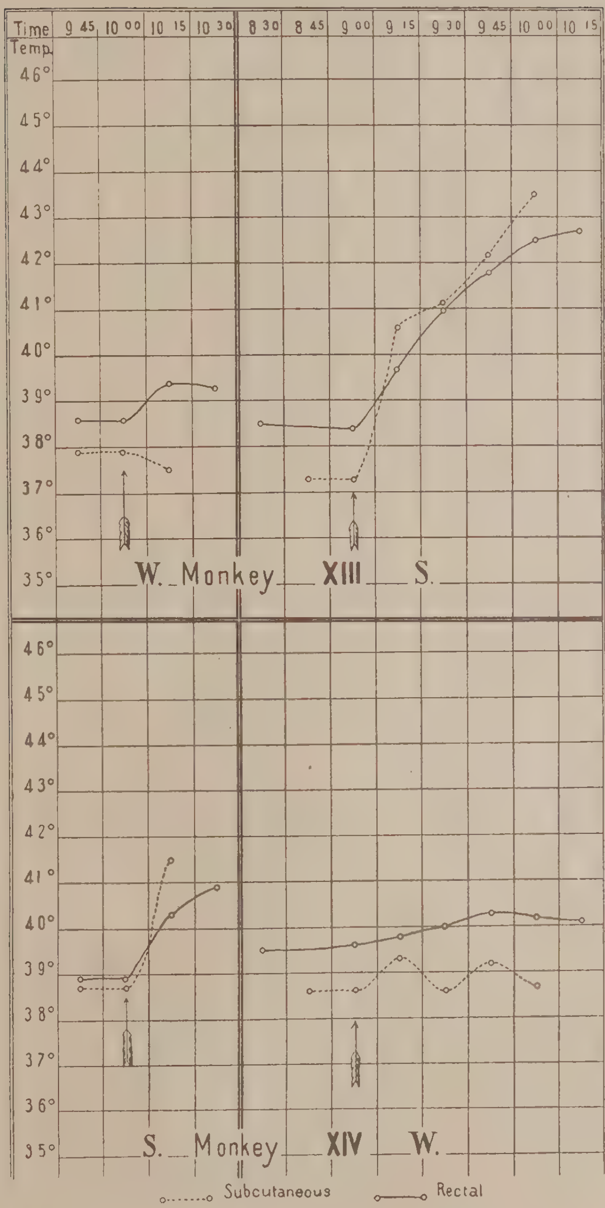
The following experiments were arranged in order to show beyond doubt that hyperthermia alone must be regarded as the true cause of the death and of the injurious effects brought about by the radiation of the sun.

Monkeys were exposed to the sun, while at the same time a strong current of air from an electric fan was blown over their bodies. Under these conditions the temperature did not rise in the same degree as in a control animal exposed at the same time, but outside the influence of the fan. Monkeys in the sun but exposed to the wind behaved more or less as did the animals under an umbrella or in the shade, no injurious effects from the sun's rays being noticed, because the motion of the air increased the loss of heat. When placed under the fan, the animals lost the excessive heat which reached them by radiation from the sun. The rays, including the ultra-violet, were nevertheless present and were absorbed by the body in the same manner and degree as by that of the control monkey. Table VI and Chart IV make the above experiments clear.

TABLE VI.—*Monkeys in the sun, with and without a blast of air from a fan.*

Date.	Remarks.	Time.	Temperature of— Monkey X in sun and wind. Subcutaneous	Monkey X in sun and wind. Rectal.	Monkey XIII in sun and wind. Subcutaeonus	Monkey XIII in sun and wind. Rectal.	Monkey XIII in sun alone. Subcutaneous	Monkey XIII in sun alone. Rectal.	Monkey XIV in sun and wind. Subcutaneous	Monkey XIV in sun and wind. Rectal.	Monkey XIV in sun alone. Subcutaneous	Monkey XIV in sun alone. Rectal.
1911.		*a. m.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*
Jan. 24	In animal house	9.50	------	------	37.9	38.6	------	------	------	------	38.7	38.9
	Exposed to sun 10 a. m	10.15	------	------	37.5	39.4	------	------	------	------	41.5	40.3
	Interrupted	10.30	------	------	------	39.3	------	------	------	------	------	40.9
Jan. 26	In animal house	8.30	------	------	------	39.5	------	------	------	------	------	38.5
		8.45	------	------	38.6	------	------	------	------	------	37.3	------
	Exposed to sun 9 a. m	9.15	------	------	39.3	39.8	------	------	------	------	40.6	39.7
		9.30	------	------	38.6	40.0	------	------	------	------	41.1	41.0
		9.45	------	------	39.2	40.3	------	------	------	------	42.2	41.8
		10.00	------	------	38.7	40.2	------	------	------	------	------	42.5
	Interrupted	10.10	------	------	------	40.1	------	------	------	------	43.5	42.7
	In animal house	10.30 10.45	36.8	38.2	------	------	38.1	39.0	38.5	39.4	------	------
	Exposed to sun 10.50 a. m	11.10	------	39.3	------	------	------	40.8	------	39.8	------	------
		11.20	37.2	------	------	------	42.7	------	39.1	------	------	------
		11.30	------	39.6	------	------	------	42.4	------	40.1	------	------
		11.40	39.5	------	------	------	44.8	------	40.8	------	------	------
		11.50	------	40.5	------	------	46.3	44.8 died.	------	40.4	------	------
		p. m. 1.00	------	[a]39.8	------	------	------	------	------	[a]40.6	------	------

[a] Left in sun under fan.



Time
9 45
10 00
10 15
10 30
8 30
8 45
9 00
9 15
9 30
9 45
10 00
10 15
Temp.
46°
45°
44°
43°
42°
41°
40°
39°
38°
37°
36°
35°
W. Monkey XIII S.
S. Monkey XIV W.
Subcutaneous
Rectal

CHART IV.

I have exposed the heads only of monkeys, by placing their bodies in a large wooden box 33 by 33 by 50 centimeters, the top of the box being fitted closely around the neck of the animal. Several holes were made in its walls to allow a free circulation of air, and, finally, the first box was placed inside a second, larger one, 50 by 50 by 48 centimeters. In this way the body was in the shade and well protected against the rays of the sun, while the head was unprotected. Monkeys have been exposed in this way for several days, from morning to afternoon, without any effect. One monkey, number 6, was insolated in this way for a total of fifty-four hours in twelve days, and the animal is still well and healthy. Temperatures up to 47° were measured in the hair of the head during several exposures, but the rectal and subcutaneous temperatures of the animal never went above the normal.

P. Schmidt [19] assumes that the heat rays from the sun, although partly absorbed by the skin and bone of the skull, at least in part penetrate the brain, and the latter organ, being very sensitive to an increase of heat, will not withstand the effects of the rays.

In my experiments with the monkeys in the box the heat rays could penetrate freely to the brain. The fact that the radiation reaches the skull appears to have no effect, if the body temperature does not rise at the same time.

Deleterious effects are only observed when the body temperature rises to febrile heights, but if this rise is prevented by a strong current of air or by protecting the greater part of the body against the heat rays, the animal will not suffer from radiation from the sun.

Post-mortem findings on monkeys dying after exposure to the sun, give the following characteristics:

Hyperæmia of the subcutaneous vessels and of all internal organs. In two monkeys small hæmorrhages in the subcutaneous tissues and in some of the muscles are observed. I can not exclude injury from the chains with which the animals were fastened as a cause of the latter condition. The alterations in heart and brain are of greater interst: All monkeys [20] which die after exposure to the sun show extensive hæmorrhages in the muscular wall of the left ventricle. These hæmorrhages are situated beneath the endocardium and for the greater part near the auriculo-ventricular border, sometimes they are also in the papillary muscles. Their extent and number varies somewhat, the smallest are rectangular, 3 by 2 millimeters. Considering the size of a small monkey's heart, these are quite severe alterations. The vessels of the dura mater are far more distended than with normal monkeys, and at several places small hæmorrhages are found. The arachnoidea is slightly raised by an exudate lying

[19] *Loc. cit.*

[20] This protocol is based on seven animals.

between it and the brain. The blood vessels of the brain are very hyperæmic; fresh, small hæmorrhages are found in several places on the basal side of the frontal lobe.

There can be no doubt but that the changes in the brain and the lesions of the heart described above were fresh and characteristic of the effects of the sun. (See Plates I and II.)

The following seems to me to be the most probable interpretation of our observations on monkeys, dogs, rabbits, and cats. The heat radiated from the sun warms the body tissues more rapidly than can be compensated for by the regulatory organism of the body. The tissues and the blood increase in temperature to a point higher than is compatible with life. Apparently the organs most susceptible to this increased heat effect are the brain and heart. It is undecided whether the lesions in the brain or heart are the most essential in causing death.

The most important fact shown by these experiments is that the outer parts of the body are heated by the sun to a greater extent than the interior. Therefore, I next endeavored to ascertain the effect of the rays of the tropical sun upon the temperatures of the skin of man.

I have not found any account of experimental work done in this line. Däubler [21] discusses the skin temperature and shows the necessity of investigations in the Tropics. The only fact which need be mentioned here is a statement by Schilling. This investigator placed a thermometer between the teeth and cheek in the mouth of a man. In the room, the thermometer showed 36°.6. The man exposed his face to the sun when the sunshine thermometer registered 55°, the thermometer in his mouth rose to 37°.05.

THE TECHNIQUE OF THE EXPERIMENTS.

Mercury thermometers, even if especially constructed for taking the skin temperature, are not suitable for this work because it is impossible to protect such instruments against the radiation of the sun. The only method suited to taking exact measurement of skin temperatures is thermoelectric, as it has been applied by Kunkel [22] and Rubner, Kisskalt,[23] Reichenbach, and Heymann [24] in the study of the normal skin temperature in men. The greatest difficulty to be overcome in the construction of such an apparatus for our studies was to keep the secondary place of junction of two metals at a constant temperature, even in the sun, and to avoid disturbing currents produced by changes in temperature of any junction between two different metals in any part of the circuit outside the thermocouple proper used for the measurements.

[21] Die Grundzüge der Tropenhygiene, Berlin, 1900.
[22] *Ztschr. f. Biol.* (1889), **25**, 55–91.
[23] *Arch. f. Hyg.* (1909), **70**, 17–39.
[24] *Ztschr. f. Hyg. u. Infectionskrankh.* (1907), **57**, 1–22.

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This danger is avoided by introducing two thermocouples in opposite directions in such places, the one neutralizing the other. If care is now taken to keep two such junctions (x and y) at equal temperatures, absolute changes in temperature will not produce current from such junctions. This is shown by the following figures, in which Scheme I shows the usual arrangement and Scheme II that employed by me.

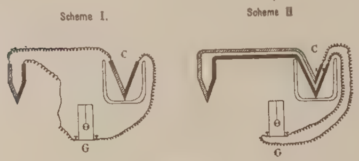


FIG. 1.

According to this principle I have constructed an apparatus suitable for taking skin temperatures, and also others for taking temperatures inside of clothing or under the skin or even in the rectum of a monkey. Figure 2 is a diagram of the thermocouple used.

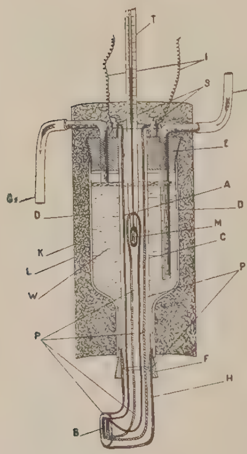


FIG. 2.

Constantan in the form of wire (black in the figure) and iron wire (dotted in the figure) each of 1 millimeter diameter were soldered together. The junction at A was kept at a constant temperature which could be read to 0°.1 by means of a sensitive normal thermometer T, the mercury bulb of which M was at the same point as A. Both wires were hammered to a fine leaf of about 0.1 millimeter thickness at the "thermometric" junction B and soldered together so that two fine plates resulted, which were carefully cleaned from all superfluous solder by sandpaper. These were placed exactly in the same level. This system of wires, surrounded by silk and insulation tape, was inclosed in its upper two-thirds in a glass tube C fitted in its lower one-third into a wooden box H of the shape of a tobacco pipe. The lower part of the glass tube and the wooden box were filled in with melted paraffine P. The lower end of the paraffine was formed into a block, the leaf-like junction B being carefully cleaned from all paraffine, so that there was left only a minute space between B and the paraffine block P. The glass tube C was now inserted into another, larger tube D by means of two rubber stoppers, E and F, E having three holes, one for D and the other two for two glass tubes G_1 and G_2, which served to circulate water. The iron wires coming from A were fixed in two pole screws S on the upper end of the glass tube C. The wires, I, led to the galvanometer. Finally, D was covered with a layer of felt and cotton K and inclosed in a cylinder of white carton paper L.

Water entering at G_1 and leaving at G_2 kept the temperature of the secondary couple A constant even in the hottest sun. G_1 was connected by a rubber tube about 3 to 4 meters in length with a tank containing 50 liters of water. The copper wires, I, with a strong coat of yellow silk insulation were coiled in the usual manner. The measurements were taken on a flat roof, while the galvanometer, connected by means of a copper key, and the wires, I, were inside the room, protected from the sun. The apparatus was freely movable and served the purpose well. I will not designate the form as ideal, but it must be remembered that it was entirely built in Manila.

The galvanometer was of the d'Arsonval principle, formerly used at the Weather Bureau and kindly loaned to me by the Rev. José Algué, S. J.

Series of test experiments were made when the apparatus was complete. B was immersed in oil baths of different temperatures in one series, in another it was inclosed in a tube fitted with a thermometer and immersed in water, the temperature of which was varied. In a third series the temperature of A was changed and that of B kept constant. Of course, all the wire connections, the galvanometer, the scale, and the position of the telescope were kept unchanged. One division of my tangential scale was equal to 0°.19 of the thermometer, and half of this interval could be read exactly and quarter intervals approximated. Readings were therefore correct to 0°.1. The deflection of the galvanometer was directly proportional to the change in temperature if the temperature limits were not greater than 8° or 9°, equal to about 40 parts on my scale.

The second type of apparatus is shown in figure 3. One constantan wire and one iron wire were soldered together. The place A was to be kept at constant temperature, and B to serve as the thermometric junction. Here the wires were hammered to fine leaf and soldered together in the form of a very flat V. They were insulated by tape and covered with a layer of silk and oilcloth. A was fixed on the mercury bulb M of a thermometer T and inclosed in a tin cylinder C so that the wires did not touch the tin box C. Two copper wires I led from the iron to the galvanometer, the places of junction between iron and copper being kept at the same temperature. The tin box C was placed in a Dewar vacuum-jacketed vessel of about 300 cubic centimeters capacity, which was filled with oil O. The Dewar vessel, resting on a piece of bamboo E, was placed in a large glass jar F which was filled with carbon K. The Dewar vessel was closed by a cork stopper G, having holes for the thermometer and the four wires. The carbon was covered by a cylindric cardboard H, which latter was covered with cotton. The two wires of constantan and iron in this drawing are shown shorter than in the apparatus, the place B was freely movable and 1 meter distant from the jar F which was kept under a large wooden box. The temperature of A was constant for one hour or more at 0.01. Test experiments were performed for each apparatus at varying intervals by placing B in oil baths of different temperatures. One division of my galvanometer scale corresponded to 0°.423 on the thermometer in the apparatus I used most, so that the sensitiveness of this thermocouple was less than one-half of that used for measuring the skin temperatures. Thus, larger temperature variations, accurate to 0°.2, could be recorded with this second type of apparatus.

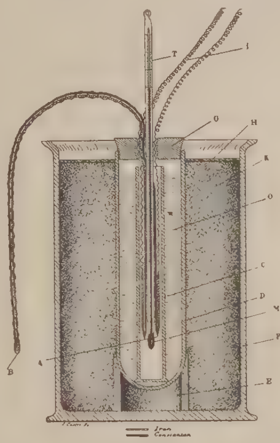


FIG. 3.

A few words are necessary concerning the technique of taking the skin temperature. Two persons must coöperate in making the measurements, one reading the galvanometer, the other handling the thermometric apparatus. The latter work was performed by a clever native

of long training, who was also able to read the galvanometer. However, I generally preferred to do this more responsible part of the work myself.

After adjusting the apparatus, taking the zero point of the galvanometer and being sure that the place of junction was being kept for at least five minutes within 0°.1, the thermometric junction was warmed in the palm of the hand and then placed on the different parts of the skin, which were to be measured. The metal leaf must just slightly touch the skin, and must be kept at one place until the galvanometer just reaches its maximum deviation; with my apparatus twenty seconds was almost more than sufficient for this purpose. Especially in experiments conducted in the sun, the place to be measured must not be touched too long, because the thermometer itself casts some shade. According to Kunkel's suggestion I have measured falling as well as rising temperatures, but I observed no difference between them.

It is more tedious to take the temperature in the hair or under clothes. Here a thermocouple of the second type must be left for three or four minutes until the maximum of deflection is reached. Care must be taken to have the metal well covered by hair in taking the temperature of the air in the hair.

The skin temperatures at different parts of the body, especially that of the head and arms, were first measured on a number of people, both white and brown, inside of a room and also in a shady place outdoors. The values obtained vary within the extreme limits of 31° to 34°, the greater part of the skin showing temperatures between 32°.5 and 33°.5. The values given by Kunkel for a room temperature of 20° are nearly 1° higher on an average than those of Rubner for temperatures of 25°.6 and 26°.5, and then my figures are for room temperatures of 26° to 30°. My figures agree very well, on an average, with those of Reichenbach and Heymann. Different places on the skin do not have exactly the same temperature; that over thicker muscular parts or over abundant fat being always higher, often as much as 1°, than that found in places where the bones lie closely under the skin. This is very pronounced over the malar bones, and on the hand. The highest temperatures generally occur on the forehead and neck; the palm of the hand is always warmer than the back, and similar variations occur in other parts of the body. Care should be taken always to measure the temperature on a dry skin; wet skin gives different values. Table VII shows normal values for the skin temperatures as obtained from a number of experiments on different people. The values given by Rubner and Kunkel are placed beside them for comparison.

TABLE VII.—*Skin temperature.*

Subject.	Place.	Palm of hand.	Back of hand.	Finger.	Finger nail.	Fore-arm out-side.	Fore-arm in-side.	Cheek over malar bone.	Tip of nose.	Fore-head.	Lobe of ear.	Chest.
		°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
C	In room 29°.5	33.4	32.6	33.0	32.3	33.3		33.3	33.1	32.8	32.3	33.8
A	In room 29°.2	33.3	32.9	33.1	31.7	33.0	32.7	33.2	32.9			
T	In room 29°.0	33.3	32.6	32.5	32.1	32.9	32.7	33.5	33.3	33.9	31.7	33.7
S	In shade outside 28°		30.7			32.8		32.8		33.4		
A	In room 26°	33.2	32.8	32.6	31.1	32.8	32.6	33.0	31.7	33.6	30.3	33.2
T	In shade outside 25°		31.0–31.4			31.8	31.4	31.2		32.4		
F	In room 30°.1					32.8	32.4	33.2	33.4	33.9		
C	In shade outside 27°		32.1			32.5		31.9		33.6		
Mc	In room 26°	32.8	32.6	32.5	30.5	32.4	33.2	32.2	33.3	33.8	30.3	33.5
Mo	In room 26°	32.4	32.2	31.6	30.9	33.0	33.0	32.4	33.6	33.9	30 7	33.3
Kunkel	Room temperature, 20°	34.4–34.8	32.5–33.2			33.7		34.1		34.1–34.4	28.8	34.4
Reichenbach and Heymann	One subject, room temperature 34°		33.6	34.1				35.8	35.0	34.6		
	Two subjects, room temperature 29°		33.2–	32.3				34.0	33.3	33.5		
			33.8	33.7				34.1	33.6	35.0		
	Three subjects, room temperature 26°.6		33.7–	32.7				32.5	32.2	32.8		
			34.1	32.8				34.2	33.6	33.3		

TABLE VII.—*Skin temperature*—Continued.

RUBNER.

Room temperature	25°.6.		26°.5.	
Individual	N.	R.	Rbch.	R.
Angle of nose	31.0	31.3	33.1	32.7
Eyelid	32.0	33.1	33.8	33.6
Hand	31.0	32.0	33.1	32.3
Skin	33.0	33.0		

I proceeded in different ways in order to study the influence of the radiation of the sun on the skin temperature. I placed a man in a sunny place in such a way that half of his face and body were exposed to the sun rays, the other side being in the shade, and the temperatures of corresponding places of both sides of the body were taken. Another arrangement was the following: The skin temperatures of several places on the skin were taken in the shade, the spot where the highest temperature of a certain region was found was marked by a very fine mark and the subject then placed in the sun, in some experiments sitting, in some lying on a cot. The temperature of the same marked places was again determined at different intervals of time after exposure. In several sets of observations I have studied a Filipino and a white man side by side.

The results of the insolation experiments are as follows: The naked human skin if exposed to the rays of the sun is warmed very quickly to about 36°. If one side is kept in the shade, the other exposed, the difference in temperature on the two sides may amount to 3°. (See Table VIII.) Above 36°, in a maximum 37°, the temperature of the skin no longer increases; on the contrary, if the exposure is continued, the temperature falls. This fall is more or less coincident with the outbreak of sweat, and the greater the secretion of sweat, the greater the fall in the temperature of the skin. The fall in skin temperature is more decided if the sweat secretion is increased by performing muscular work in the hot sun. (See Table VIII.)

TABLE VIII.—*Characteristic records of experiments testing human skin temperature radiated by the sun. Figures, except pyrheliometer readings, in degrees centigrade.*

[Fr. Filipino, upper half without clothes ten minutes in sun. Sunny side, 35°.8 to 36°.3; shaded side, 32°.1 to 32°.4.]

JANUARY 4, 1911.

(Pyrheliometer reading 9.20 a. m., 680; 9.40 a. m., 720.)

T. American, brown hair.	Side measured.	Arm.	Cheek.	Forehead.	Chest.[a]
Air temperature in shade 24°.2		31.4 to 31.8	31.0 to 31.2	31.0 to 32.4	32.9
Air temperature in shade 24°.7. One side of face 10 to 15 minutes in sun, other side in shade, corresponding points.	Sunny side	35.8	35.2		41.8
	Shady side	31.5 to 31.9	31.3 to 31.9	31.7 to 31.9	

[a] Between shirt and undershirt. Air in hair after exposure 46°.0.

JANUARY 6, 1911.

Ma. Filipino.	Face.	Forehead.	Palm of hand.	Back of hand.	Chest.
Muscular work in sun, severely perspiring	32.4 to 32.9	33.5 to 33.7	33.3 to 33.9	32.8 to 33.1	33.9 to 34.5

JANUARY 3, 1911.

(Pyrheliometer reading 10 a. m., 845; 10.30 a. m., 865.)

Ma. Filipino.	Face.	Forehead.	Arm.	Tip of nose.	In hair.	Chest.
Air temperature in shade 28°.9	31.5 to 31.9	32.5	32.1 to 32.5	31.7		32.5
After 30 minutes in sun	35.4	34.9	36.9	34.1	44.0	39.8

JANUARY 10, 1911.

(Pyrheliometer reading 9.30 a. m., 845; 9.40 a. m., 850.)

Individual.	Condition.	Arm.	Hand.	Forehead.	Cheek.	In hair.	Axilla.[a]
S. American, fair hair.	In shade 28°	32.8	[b]30.7	33.4	32.8	35.2	
	After 15 minutes in sun, sweat in fine droplets.	35.6	35.6	34.8	34.0	44.1	37.6
F. Filipino, brown skin, black hair.	After 15 minutes in sun, same day, directly after S.	33.4 to 34.8	34.6 to 34.8	34.3	33.9	46.7	

[a] Between shirt and undershirt. [b] Has wet hands.

TABLE VIII.—*Characteristic records of experiments, etc.*—Continued.

JANUARY 9, 1911.

(Pyrheliometer reading 9.35 a. m., 840; 9.45 a. m., 855.)

The same marked points were measured.

Individual.	Condition.	Face.	Fore head.	Arm.	Hand.	Neck (back)	In hair.	Axilla.
Gz. Spanish mestizo, white skin, hair dark brown.	In shade 10.30 a. m. Air temperature 27°.	32.4	33.4	33.0	32.8	33.0	32.1	--------
	11.15 a. m. after 25 to 30 minutes in sun (slightly sweating).	36.5	36.3	37.1	36.5	[c] 35.0	46.8	--------
	11.30 a. m. after muscular work in sun, freely sweating.	33.0	32.4	33.2	33.0	34.0	--------	--------
Cs. Filipino, dark brown skin, black hair.	10.30 a. m. as above	32.6	33.8	32.8	31.6	33.2	37.4	36.3
	11.15 a. m. as above	36.3	36.1	36.8	35.5	[c] 34.6	46.8	38.7
	11.30 a. m. as above	32.6	33.6	33.4	31.8	32.8	--------	--------

[c] Not directly in sun.

JANUARY 17, 1911.

(Pyrheliometer reading 9.40 a. m., 750.)

Individual, the same, lying on field bed.	Condition.	Arm.	Hand.	Fore-head.	Face.		Neck.	In hair.	Axilla.
					Cheek.	On malar.			
Gz. Spanish mestizo, white skin, hair dark brown.	9.50 a. m. in shade air temperature 27 to 27°.5.	32.5	32.7	33.3	33.1	32.7	33.7	27.8	36.3
	10.05 a. m. 10 minutes in sun.	36.2	35.8	36.2	35.2	34.8	35.4	--------	37.4
	10.25 a. m. 30 minutes in sun.	35.0	35.0	35.4	35.6	35.4	35.0	41.2	38.2
	10.55 a. m. 1 hour in sun.	34.6	34.6	35.4	35.2	35.0	35.0	47.9	39.7
Cs. Filipino, dark brown skin, black hair.	9.50 a. m. as above	32.3	32.5	33.5	32.9	31.9	33.3	28.2	--------
	10.05 a. m. as above	36.2	34.2	35.6	34.1	34.4	34.8	--------	--------
	10.25 a. m. as above	35.0	34.2	34.8	34.4	34.2	34.4	44.2	--------
	10.55 a. m. as above	34.8	34.2	34.8	34.8	34.6	34.4	50.1	--------

TABLE VIII.—*Characteristic records of experiments, etc.*—Continued.

JANUARY 28, 1911.

Individual.	Time.	Arm.	Cheek.	Fore-head.	Neck.	In hair.
B. American, brown hair	9.45 a. m. in shade	32.5	33.3	33.9	34.1	33.1
	9.50 a. m. exposed to sun					
	9.55 a. m. exposed to sun	34.7	35.9	35.5	36.8	
	10 a. m. exposed to sun	35.5	36.6	36.4	37.0	39.1
	10.10 a. m. exposed to sun	35.7	37.4	35.9	36.8	38.9
	10.20 a. m. exposed to sun	36.9	36.3	35.6	36.5	
Or. Filipino, dense black hair.	9.45 a. m. in shade	33.4	34.0	34.4	34.2	32.7
	9.50 a. m. exposed to sun					
	10 a. m. exposed to sun	37.2	36.6	35.9	35.7	43.4
	10.10 a. m. exposed to sun	37.2	36.4	35.9	35.7	44.0
	10.20 a. m. exposed to sun	36.1	35.4	35.2	35.4	

The figures given for pyrheliometer values are the number of milliamperes necessary to produce the current which warms one German silver leaf to the same temperature as the other exposed to the sun. They do not give absolute figures (see discussion, p. 119), but they indicate thus far the relative value of the radiation of the sun on the different days. Only clear days were chosen for experiments, and but slight differences in the radiated heat of the sun were found.

The temperature in the hair of an uncovered head increases to much higher values than those of the skin, and here no fall is observed. The color of the hair, as well as its thickness, is of great importance. In the black, dense hair of a native of the Philippines, the temperature may rise to 50°.1 within one hour, and approximately 45° as a rule is obtained within thirty minutes.

Kunkel states that he has never observed skin temperatures above 35°.5. In the tropical sun I have obtained slightly higher values, the highest being 37°.4, but generally 36°.5 was the upper limit.

Table IX shows a comparative study of the behavior of white and brown skin. In the sun, the white skin is always slightly hotter than the brown and with the brown skin the fall in temperature after a certain time of exposure is more pronounced. The heat absorbed by a brown skin is greater than the heat absorbed by a white skin in the same length of time. Therefore, it would seem as if the rise in temperature should take place more quickly in colored than in white skin. This has been experimentally proved to be true with dead skin by P. Schmidt [25] and Eykmann.[26] Yet, just the reverse is true in living men. Brown skin will absorb a greater quantity of rays than white, but being more quickly heated, the point where sweat secretion begins is reached earlier, and as soon as this point is reached the skin is cooled by water evaporation. With the white skin, this process takes place more slowly and it

[25] *Loc. cit.*

[26] *Virchows Arch.* (1895), **140**, 125–157.

must be for this reason that the brown skin, while absorbing more heat, is found to have lower temperatures than the white skin under similar conditions. The regulatory apparatus of the brown is more sensitive and works more promptly and successfully. This statement deserves attention, because the experiments on dead skin only served to convey a wrong impression of the behavior of colored and white skin when exposed to the sun's rays.

TABLE IX.—*Comparative increase in temperature of white skin and brown skin when exposed to sun, as obtained in the three foregoing experiments.*

Time in minutes.		Temperature of cheek.					
		I.		II.		III.	
In sun.	In shade.	White.	Brown.	White.	Brown.	White.	Brown.
		°C.	°C.	°C.	°C.	°C.	°C.
0	0	32.4	32.6	33.1	32.9	33.3	34.0
10	--------	--------	--------	35.2	34.1	36.6	36.6
20	--------	36.5	36.3	--------	--------	37.4	36.4
30	--------	--------	--------	35.6	34.4	36.3	35.4
40	--------	[a]33.0	[a]32.6	--------	--------	--------	--------
50	--------	--------	--------	--------	--------	--------	--------
60	--------	--------	--------	35.2	34.8	--------	--------
		Temperature of forehead.					
0	0	33.4	33.8	33.3	33.5	33.9	34.4
10	--------	--------	--------	36.2	35.6	36.4	35.9
20	--------	36.3	36.1	--------	--------	35.9	35.4
30	--------	--------	--------	35.4	34.8	35.6	35.2
50	--------	[a]32.4	[a]33.6	--------	--------	--------	--------
60	--------	--------	--------	35.4	34.8	--------	--------

[a] Muscular work.

It is a matter of general observation that, at a time when the white man is perspiring over his entire body and the sweat is dropping from his face and forehead, the brown man shows only a fine, velvet like layer on his skin. It is not the sweat which *we see,* but that which we do *not see* which exerts the cooling effect; in other words, the water *evaporated,* not the water *secreted* is of value. Sweat which drops is water lost from the body without the corresponding cooling effect. There is economy in sweating, and the most economical way is to secrete no more water than can and will be evaporated. Hypersecretion is useless, and it deprives the body of water. It seems to me that the brown man is superior to the white in this economy of sweating, and we find an expression of that superiority in the lower skin temperature of the brown man in the sun. It is as yet undecided whether the result is due to the color, or if the nervous regulation of the sweat glands, or

even the anatomic build of the latter, is not different in the tropical races from that of white men. Däubler states that the negro has larger and better developed sweat glands than the white man. The fact that Rubner could not find greater water evaporation in negroes than in Europeans at high air temperatures does not contradict my supposition, for, if I am right, the dark skin is superior to the white only in the sun, where radiated heat is absorbed more intensively by the one than the other.

Certain parts of the body, in brown as well as in white men, seem to sweat earlier and more intensively than others. For instance, the forehead always secretes sweat earlier than the arm. As a result, the temperature on the forehead has begun to fall while that of the arms is still rising. In the sun the ultimate temperatures observed on the arm are generally higher than those on the forehead.

The results obtained so far indicate that the temperature of the human skin increases in the sun, but does not reach the normal body temperature. In animals without sweat glands, the skin temperature rises above febrile heights and the tissues lying underneath are heated. On the other hand, penetration of heat through the human skin seems improbable, the effect of the rays absorbed being neutralized by water evaporation on the skin. The more perfect this water evaporation is, the better the normal body temperature may be maintained. The behavior of normal dogs as compared with those which have undergone tracheotomy shows this fact plainly. Monkeys exposed to the sun in Manila die in little over one hour because of their limited capacity to evaporate water, while man, with his well-developed sweat glands resists the same climatic conditions for a much longer period without detriment.

My experiments demonstrate the enormous physiologic and hygienic importance of ample water evaporation in the Tropics. We are the better off, the better we can lose heat by water evaporation.

Water evaporation from the skin is the most complete when a large part of the skin area is uncovered. The native laborer in the Tropics generally wears but little clothing, often only a breechclout. On the other hand, the white skin can not withstand the direct rays of the sun. Sunburn, *erythema solare,* or even more severe lesions, are produced by the sun's rays, while such injuries rarely occur with the brown skin. The range of the rays which produces this effect is not entirely known, but it is to be presumed that they lie in the violet end of the spectrum and beyond. Now, because of this effect the colored man can expose his body to the tropical sun, but the white man must keep covered. Necessarily, under the same climatic conditions, water evaporation from the skin when uncovered is much more free than that from the same skin covered with clothes. If we further consider that the colored skin

seems to be so arranged as to provide for a greater economy in sweating and water evaporation when exposed to the sun, we must conclude that the colored man, as regards his physical heat regulation in the tropical sunlight, is in a better position than the white man.

The temperature conditions surrounding the parts of the body covered by clothes depend principally on the class of clothing worn.[27] It will be important to learn what proportion of the heat rays are absorbed by the clothes, how freely they permit of water evaporation from the skin and how far free circulation of air is possible within them. The question of the extent to which heat regulation in the Tropics is affected by different kinds of clothing is of great physiologic and hygienic importance, and this problem will be considered in future investigations.

While men, by reason of their superior facilities for evaporating water, are able to counteract the radiated heat from the sun more efficiently than dogs, cats, rabbits, or monkeys, this heat is not without its influence on the human being. The water loss which equalizes the radiated heat is considerable. A man lying quietly in the sun, in one hour lost 280 grams in weight. The water actually lost from the body must have been considerably more, because the sweat absorbed by the clothing is not included in the above figure. The pulse rate of a man sitting quietly in the sun increases on an average about 10 to 12 beats over the number for the same man in the shade. I have proved this by several observations. The quantity of air respired is also increased. An average of a number of observations shows the following:

Quantity of air respired in liters per minute.

Number of observations.	Minimum.	Maximum.	Average.
22 in shade	4.70	5.98	5.28
17 in sun	5.83	7.90	6.74

Therefore, the volume of air respired increases 23 per cent, or from 316.8 liters per hour in the shade to 390.4 liters in the sun.

If heat production within the body is very great, as it is during strenuous muscular work, then, even in a temperate climate, the heat-regulating apparatus is not able to diminish the heat by water evaporation as quickly as it is produced, and as a result rises in the body temperature are observed (Zuntz und Schumburg).[28] If at the same time the body is also heated by radiation, the heat accumulated must be greater with a corresponding rise in body temperature.

[27] Zuntz, Löwy, Müller und Caspari, Höhenklima und Bergwanderungen in ihrer Wirkung auf den Menschen, Berlin (1906).

[28] Studien zu einer Physiologie des Marsches, Berlin.

This increased body temperature probably accounts for many of the accidents which usually are described as *sun stroke* or *heat stroke;* however, several strokes of this kind, some even fatal, have been reported with but slight rises in temperature. No reasonable explanation of these in relation to the heat rays have been given. I wish to offer one explanation which seems to me quite plausible: Under unfavorable climatic conditions during muscular work, P. Schmidt has observed water losses as great as 1 kilogram per hour. The body can withstand a loss of water in a maximum of 10 per cent of its weight. An acute loss of 3 to 4 kilograms within a few hours, according to our experience with animals (Czerny), necessarily must result in severe disturbances, collapse or even death. It seems quite reasonable to assume that an excessive, continued water evaporation, while avoiding a rise of the body temperature, may lead to collapse, similar to that observed in cholera if the water lost from the body is not replaced.

SUMMARY.

1. Under climatic conditions, even during the cooler seasons of the year in Manila, animals, such as rabbits and monkeys which by nature have only a limited power of physical heat regulation, or animals the physical heat regulation of which is artificially inhibited (tracheotomized dogs) die if exposed to the sun, the body temperature rising to febrile heights. If the same animals are protected from the rays of the sun, or if the increase of heat due to radiation from the sun is compensated by an increased loss such as would be brought about by a strong wind, then the animals suffer no discomfort. Insolation of the skull alone is without effect if the body temperature is kept within normal limits.

2. The post-mortem findings on the animals dying as a result of insolation show decided hæmorrhagic lesions of the meninges in the brain, and in monkeys, in the heart.

3. In animals without sweat glands the subcutaneous tissues are heated by the radiated heat from the sun to temperatures above those compatible with life.

4. The human skin if exposed to the sun is warmed to about 3° to 4° above the normal skin temperature (32°.5 to 33°.5). An increase, even to the normal body temperature, is prevented by evaporation of sweat. The cooling effect of the sweat secretion causes a fall of the skin temperature even if insolation is continued during longer periods.

5. The brown skin of Malays, while theoretically absorbing more heat in the sun, shows a smaller rise in temperature in the tropical sun than the skin of white men under similar conditions. As an explanation, it is believed that an earlier and better water evaporation by sweat secretion takes place.

6. The air in the human hair, especially in black hair, under the

influence of the tropical sun acquires temperatures far above those compatible with life.

7. It is demonstrated that in the tropical sun a man with a colored skin is in a better position as regards heat regulation than is a man with a white skin.

8. Types of apparatus suitable for testing temperatures thermoelectrically are described.

In concluding, I wish to invite attention to more general biologic questions as regards climate. The monkey, whose home is in the Tropics, withstands the sun less readily than any other animal I have observed, including even the white man. Of course, the monkey does not live in the fields; his home is in the forest, into which only a small proportion of the direct rays of the sun can enter. He instinctively avoids exposing himself to the sun for more than a few minutes. The same is true of the native of the Tropics, if he is left to his own customs. Even if he is otherwise nearly naked, he often wears a large hat-like arrangement which shades not only his head but his body.

Certain features of any climate must always be met. The temperate climate is only suitable for man if he protects his body against it. Our chemical heat regulation would not be sufficient to allow us to withstand the cold of temperate climates without the protection of clothes and houses.

The question of the best way to live in a certain climate will always be to learn how to avoid its injurious effects, or to secure protection against them. No better example than the monkey, which is killed by the tropical sun in from one to two hours, can be found to confirm the above statements.

ILLUSTRATIONS.

TEXT FIGURES.

PLATE I.

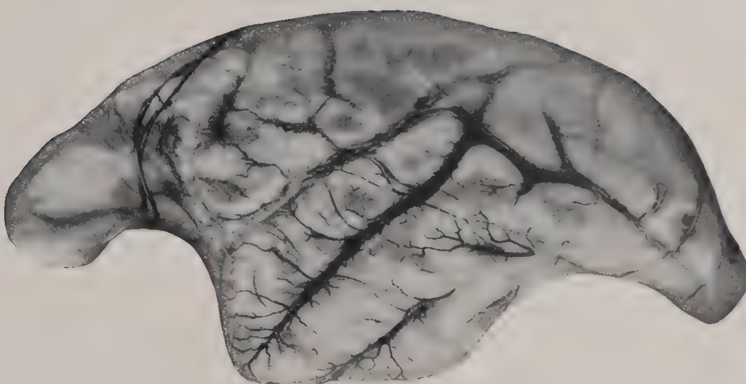


PLATE II.

THE ERADICATION OF BERIBERI FROM THE PHILIPPINE (NATIVE) SCOUTS BY MEANS OF A SIMPLE CHANGE IN THEIR DIETARY.[1]

By WESTON P. CHAMBERLAIN.[2]

I. CHANGES IN THE FILIPINO RATION FOR SCOUTS[3] IN THE YEAR 1910.

Influenced by the work of Braddon, Stanton, Fraser and others on the effects of highly milled rice, this Board investigated in 18 Scout companies the incidence of beriberi as related to the diet actually consumed by the men.[4] As a result of the knowledge gained the Board (then consisting of Captains Phalen and Kilbourne) on September 30, 1909, recommended that the following changes be made in the Filipino Scout ration:

1. That the daily amount of rice used per man be limited to 16 ounces instead of the 20 ounces formerly allowed.

[1] Read, with permission of the Chief Surgeon, Philippines Division, before the Philippine Islands Medical Association at Manila, P. I., February 22 to 24, 1911.

[2] Major, Medical Corps, United States Army; President of the Board for the Study of Tropical Diseases as they exist in the Philippine Islands.

[3] The organization known as the "Philippine Scouts" consists of approximately 5,000 Filipino enlisted men serving as infantry. The commissioned officers are Americans. This organization is under the control of and supported by the War Department of the United States and is scattered in small garrisons throughout the Archipelago. The Philippines Constabulary, referred to later, is under the control of the Insular Government and has an enlisted strength of about 4,000 Filipinos. It is much more widely scattered in smaller garrisons than is the Scout organization and it has an entirely different system of rationing its men.

[4] Kilbourne, E. D., Food Salts in Relation to Beriberi. *This Journal, Sec. B* (1910), 5, 127.

2. That Filipino number 2 rice (an undermilled article) be substituted for choice Saigon rice (highly milled.)[5]

3. That 1.6 ounces of beans be added to the ration in place of the 4 ounces of rice not used.

4. That the issue be authorized of canned tomatoes in lieu of an equal quantity of potatoes, but not to exceed 20 per cent of the total issue.

5. That onions be issued on the same terms as tomatoes instead of allowing them to be substituted for the entire quantity of potatoes.

6. That no savings be permitted upon the ration of fresh beef and potatoes or their substitutive articles.

The components of the Philippine ration at the time of these recommendations are shown in the following table:

TABLE I.—*Filipino ration, Army Regulations 1908, paragraph 1220.*

Component articles.	Quantities.	Substitutive articles.	Quantities.
Beef, fresh	12 ounces	Bacon	8 ounces.
		Canned meat	8 ounces.
		Fish, canned	12 ounces.
		Fish, fresh	12 ounces.
Flour	8 ounces	Hard bread	8 ounces.
Baking powder, when in field and ovens are not available	0.32 ounce		
Rice	20 ounces		
Potatoes	8 ounces	Onions	8 ounces.
Coffee, roasted and ground	1 ounce		
Sugar	2 ounces		
Vinegar	0.08 gill		
Salt	0.64 ounce		
Pepper, black	0.02 ounce		

It should be explained for the benefit of those not in the military service that such a ration does not indicate exactly what a company eats. "Savings" can be and usually are made on some components of the ration

[5] "Polished rice," "highly milled rice," "scoured rice" and "white rice" have been used by various writers as synonyms. They are contrasted with "undermilled rice," "medium milled rice," "unpolished rice," and "red rice," all four terms indicating that more or less pericarp has been left on the grain. Some rices have red pericarp and others have white. If the red pericarp is all milled off, the grain is then white. Therefore, the use of the term "white rice" to indicate a highly milled article is objectionable because it leads to confusion between milling processes and color of pericarp.

As far as the presence of adherent pericarp is concerned undermilled rice corresponds with the "cured rice" of India (not used in the Philippines) and the "Filipino number 2" rice of the Scout ration prescribed by General Orders, No. 24.

and the money value thereof used to purchase other articles of the ration, or articles not on the ration, for the purpose of adding variety to the company bill of fare; or the money value of the articles saved may be added to the company fund.

The first and third recommendations and indirectly that portion of the sixth recommendation relating to the saving of fresh beef were made effective by the following instructions of the division commander and must have gone into operation at the individual posts between the middle of November, 1909, and the first part of January, 1910.

HEADQUARTERS, PHILIPPINES DIVISION,
Manila, November 3, 1909.

The COMMANDING GENERAL,
Department of Luzon (Visayas, Mindanao, and Camp Avery), Manila.

SIR: The division commander directs that the attention of all Scout battalion and company commanders be called to the directions of the Secretary of War, that, with the exception of the meat component of the ration, Scouts will be rationed as largely as possible on native food products; to the recommendation of the Board for the Study of Tropical Diseases, that the amount of rice be reduced from 20 ounces to 16 ounces per ration, and that beans to the extent of 1.6 ounce per ration be used in lieu of rice; to Army regulation 1262, under which native food products not procurable locally can be obtained from the subsistence department as exceptional articles.

In view of the above, company commanders should not draw rice to exceed 16 ounces per ration. Savings should be made as largely as possible on potatoes, onions and coffee, and native products, such as camotes, mongos, squash, ginger root, etc., be purchased.

Very respectfully,

(Signed) J. T. KERR, *Adjutant-General.*

Furthermore, steps were taken by the subsistence department to obtain a Filipino number 2 rice (undermilled) to replace the highly milled or "polished" Saigon rice which was used for the Scouts. None of this undermilled rice, however, went into use until about August (as will be shown below). We consider that the provision of undermilled rice combined with the above instructions of the division commander would have put into effect the most essential features of the Board's original recommendations.

The situation was complicated by the arrival, toward the end of March, 1910, of General Orders, No. 24, War Department, February, 1910. This order greatly altered the Scout dietary. The components of the ration thus prescribed are shown below:

TABLE II.—*Filipino ration, General Orders, No. 24, War Department, 1910.*[e]

Component articles.	Quantities.	Substitutive articles.	Quantities.
Beef, fresh	12 ounces	Bacon	8 ounces.
		Canned meat	8 ounces.
		Fish, canned	12 ounces.
		Fish, fresh	12 ounces.
Flour	8 ounces	Hard bread	8 ounces.
Baking powder, when in field and ovens are not available.	0.32 ounce		
Rice, *Filipino No. 2*	16 ounces	*Rice, Saigon (when Filipino No. 2 can not be obtained).*	
Camotes[a]	8 ounces		
Mongos	4 ounces		
Coffee, roasted and ground	0.5 ounce		
Ginger root	0.5 ounce		
Sugar	2 ounces		
Vinegar	0.08 gill		
Salt	0.64 ounce		
Pepper, black	0.02 ounce		

[a] The *camote* is a vegetable allied to the sweet potato. The *mongo* (*Phaseolus radiatus* Linn.) is allied to the bean. "Filipino No. 2" rice as the term is used in this ration means an undermilled rice.

The Board had no knowledge of this new ration prior to the promulgation of the order in the Philippine Islands. It will be seen, however, that the order carried out in spirit the three most important recommendations of the Board in that an undermilled rice (Filipino No. 2) is prescribed in the amount of 16 ounces daily and mongos (equivalent to beans) are added to the ration in lieu of the 4 ounces of rice taken away.

DATES ON WHICH THE COMPONENTS OF THE NEW RATION WENT INTO USE.

The subsistence department at once proceeded to obtain mongos and camotes, but in order to use up the large supply of Saigon rice on hand a delay occurred in the issue of the Filipino number 2 rice. In determining the dates on which the Scouts would actually begin to subsist on these new articles one must consider the date the article was delivered to the quartermaster's department in Manila for shipment to posts, the time of sailing of the transports, the time spent on the voyage, the time spent in unloading and the delays (due to rations being drawn

[e] Since July 1, 1910, Scout companies have been authorized to make money savings on the entire ration and purchase therewith such articles as they need, but the purchases must be made from the subsistence department, provided it has the desired articles in stock. This new system does not materially affect the feeding of the Scouts. The money value of the ration at the present time is about 14 cents United States currency.

only three times a month) which would occur after the articles actually reached the commissary officer at the Scout post and which could not average less than five days. All of these factors except the last have been embodied in Table III. From a careful study of all the conditions it is possible to set a date before which none of the articles could have become a part of the diet, and a period during which they must have been gradually going into use.

None of the Filipino number 2 rice could by any possibility have been in use prior to July 15, 1910, and but little could have been issued at any time in July. In August the issue became more general, and probably all Scout companies were supplied by the last of August or first part of September.

The first consignments of mongos and camotes were shipped simultaneously and none left Manila until May 20, 1910. Under the most favorable conditions of unloading and prompt issue one Scout command (three companies) *might* have put mongos and camotes into use as early as May 21, but probably did not. No other Scouts could possibly have been using these camotes and mongos before May 25 even granting that they were issued at once on arrival at the station. About half of the Scouts could not have received any mongos and camotes until well into June. The issue to the last of the posts was not completed till the first part of July.

The first shipments of ginger root occurred at the same time as those of camotes and mongos. In some of the Mindanao posts ginger root was received about ten days sooner than camotes and mongos, but not, however, before the last two or three days of May.

The importance of fixing these dates will be appreciated when the beriberi statistics for 1910 are considered. The details for the shipments are shown in the following table:

TABLE III.

Article of ration.	First received in depot commissary, Manila.	Dates first invoices were turned over to the quartermaster's department for shipment to Scout posts in the Department of—		
		Luzon.	Visayas.	Mindanao.
No. 2 rice	July 5, 1910	July 14 to Aug. 23	July 14 to Aug. 3	July 5[a] to Aug. 5.
Camotes	May 20, 1910	May 20 to May 23[b]	May 20 to June 2[c]	June 3 to June 8.[c]
Mongos	May 18, 1910	May 19 to May 25[d]	On May 18	June 3 to July 7.
Ginger root	May 19, 1910	May 20 to June 17	May 20 to June 2	May 19 to July 8.
Time consumed in transit to individual posts.		2 to 16 days; average, 4½.	4 to 11 days; average, 7½.	4 to 18 days; average, 10.

[a] This July 5 shipment reached Cotabato on July 13 and Torrey Barracks and Davao on July 15. Issues to the troops were not to be expected immediately after it arrived.

[b] One post rationed August 17.

[c] One post rationed July 2.

[d] One post rationed June 3.

THE CHARACTER OF THE RICE SELECTED.

The Filipino number 2 rice selected by the subsistence department was examined as regards its pericarp by this Board and approved. It was a mixed rice, having grains with red pericarp mingled with those having a white pericarp. A large amount of the pericarp had been left on the grain. By analysis made in the office of the Surgeon-General of the Army it was found to contain, nitrogen 1.32 per cent, potash (K_2O) 0.223 per cent and phosphoric acid (P_2O_5) 0.489 per cent, whereas the polished rice it replaced had contained only 1.08 per cent nitrogen, 0.098 per cent potash and 0.260 per cent phosphoric acid.

The mixed red and white rice was approved for two reasons. First, it was possible to determine at a glance, without staining, whether sufficient pericarp remained on the kernel. Second, it was thought that if this red rice proved unwelcome to the Scouts a change could be made in subsequent contracts to an undermilled *white* rice which, by contrast with the red rice, would then probably prove acceptable, whereas it would undoubtedly have aroused hostility if substituted immediately for the highly polished article the subsistence department has in the past been issuing to the Scouts and which they have come to like because of its snowy appearance when cooked. It is probable that few of the Scouts were used to such a highly polished article prior to their enlistment, and in many sections of the Islands a red, undermilled rice is commonly used. After several years in the military service where they received only the highest grade of polished rice these natives have become spoiled in this respect, and it was to be anticipated that the substitution of an undermilled rice, whether red or white, would be distasteful to them for a time.

The truth of the above reasoning has been demonstrated by the experience of the Philippine Civil Government. At the Culion leper colony the inmates objected to an undermilled red rice, but apparently are satisfied with an equally undermilled rice having white pericarp. The use of undermilled rice has eradicated beriberi from that and other civil institutions in the Philippines, and at this point it may be mentioned that on May 4, 1909, Governor-General Forbes issued Executive Order No. 37, forbidding the use of polished rice in any public institution.

DISSATISFACTION WITH THE NEW FILIPINO RATION.

For many reasons the new Filipino ration, as ordered by General Orders, No. 24, caused dissatisfaction among the troops and in the subsistence department. The Filipino number 2 rice, in addition to being undermilled, contained many unhusked kernels and much broken grain and dirt and furthermore was thought to become infested with worms and insects more readily than did polished rice. The camotes did not

keep well and neither they nor the mongos could always be obtained in sufficient quantities in the Island markets. Therefore, some had to be imported. The ginger root was not acceptable to the Scout as a partial substitute for coffee. Neither mongos nor camotes met with favor as constant articles of diet.

RETURN TO THE OLD FILIPINO RATION.

The dietary problem was still further changed on November 7, 1910, when General Orders, No. 24, prescribing the new Filipino ration, was revoked by a cablegram from Washington. The question of diet therefore reverts to its former status, viz, the old Filipino ration (Table I) with 20 ounces of polished rice as a component. There is, however, so much Filipino number 2 rice on hand in the subsistence depots that its issue and use will continue for several months. Meantime the Board is making efforts to have the ration modified to the extent of forbidding the use of more than 16 ounces of rice daily per man and prescribing a first grade undermilled rice with white pericarp, in place of the highly milled grain which the ration now calls for.

LESSON LEARNED FROM USE OF FILIPINO NUMBER 2 RICE.

A very desirable lesson has been learned from the issue of the Filipino number 2 rice. The Board now recognizes that the term Filipino number 2 rice was an unfortunate one for two reasons. First, some samples of commercial Filipino number 2 rice are highly milled or polished; second, this rice is second grade not only in respect to its milling (i. e., pericarp removal) but also as to its husking and screening and probably at times is produced from an inferior quality of *palay* (padi). The original selection by the Board of Filipino number 2 rice as the beriberi preventing type was due to the fact that when our recommendation was made no other kind of undermilled rice could be found in the Manila market and there was much less knowledge of and interest in the subject, on the part of the rice dealers, than is now the case.

What the Board now recommends for the Scouts is a rice of the highest grade and in all respects like the "choice rice" of the subsistence department except that it is "undermilled" (i. e., has much of its pericarp left on). In this connection the use of the word "milling" refers only to the process of decortication carried on (in most mills) between a stone cone and the metal-gauze case within which the stone revolves, and does not have reference to the other processes carried out in the building, such as husking, winnowing, screening and polishing between sheep skin buffers. We also recommend that, for appearance sake only, this rice be prepared from *palay* having a white pericarp.

Such a rice can now be produced in these Islands and the millers state that its keeping qualities should be equal to those of highly milled rice. The Board has recently examined samples of a rice from Siam styled "Asylum No. IV." This is an undermilled rice prepared under the supervision of Doctor Highet, of Bangkok, who states that it has been used for six months in an asylum and found to prevent the development of beriberi. Except for an occassional red grain, the rice is white and has much the larger part of the pericarp remaining on the kernels. There are very few unhusked or badly broken grains. The dealers state that they can furnish in quantity rice conforming to this standard. This rice is found by the Bureau of Science to contain 0.52 per cent of phosphorus pentoxide and this we consider an index of its safety. It appears that rices containing over 0.4 per cent of phosphorus pentoxide will prevent beriberi, and this can be used as an indicator, irrespective of whether or not one accepts the phosphorus theory of beriberi production.

II. GREAT REDUCTION IN THE BERIBERI ADMISSION RATE IN THE YEAR 1910.

The numerous changes which have occurred in the Scout ration during the year 1910 render necessary a somewhat elaborate analysis of the situation before one can decide to which factors should be ascribed any peculiarity which may be found in the beriberi rate for the period. From the standpoint of scientific dietetic study it is unfortunate that so many alterations were made in such close sequence.

Let us now determine if any peculiarity is manifest in the beriberi admission rate for the year 1910. A glance at the following statistical tables will settle the question by showing an unprecedented decrease in the amount of that disease among the Scouts for the calendar year 1910.

TABLE IV.—*Beriberi statistics for Philippine Scouts, calendar years 1902 to 1910.*

Calendar year.	Mean strength Surgeon-General's Office.	Admissions.		Deaths.		Discharges for disability.	
		Number.	Rate per 1,000.	Number.	Rate per 1,000.	Number.	Rate per 1,000.
1902	4,826	598	123.92	29	6.01	2	0.41
1903	4,789	614	128.21	22	4.59	5	1.04
1904	4,610	334	74.62	7	1.52	6	1.30
1905	4,732	170	35.93	6	1.21	1	0.02
1906	4,759	176	36.98	9	1.79	6	1.19
1907	4,679	115	24.58	6	1.28	3	0.54
1908	5,085	618	121.54	7	1.35	13	2.50
1909	5,369	558	103.93	12	2.17	33	5.96
1910	5,422	50	10.00	2	0.36	3	0.55

TABLE V.—*Admissions for beriberi by months, calendar years 1908 to 1910.*[7]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908	14	34	102	23	51	33	55	39	63	59	88	63	624
1909	138	89	96	88	38	24	28	36	7	27	22	11	604
1910	19	8	12	3	4	1	0	2	0	0	0	1	50

From a study of Table IV, it is plain that beriberi was very prevalent during 1902 and 1903 and that there was a *slow* and *gradual* yearly decrease in its incidence down to 1907, when the total number of admissions had fallen to 115. In 1908 there was a sudden increase to 618 admissions, the largest number recorded in any one year. In 1909 the number of admissions was but little less, 558, while for the year 1910 there were only 50 admissions, a most significant drop when it is considered that all the sanitary conditions were unchanged except the diet. The drop in the death rate and in the discharge rate are equally remarkable.

III. RELATIONSHIP BETWEEN DECREASE OF BERIBERI AND CHANGES IN DIETARY.

It will be seen in Table V that 39 (or 80 per cent) of the admissions occurring in 1910 appeared in the first three months of the year, a time when the ration changes recommended by the Board had been in effect but a short time, or were just being put into effect. It is important to note that some decrease in admissions began in the last quarter of 1909 and that just prior to that time members of the Board had visited many Scout posts, especially those where the disease was rife, and had investigated the dietary actually in use and advised company commanders to limit the daily consumption of rice and to use liberally the other components of the ration instead of economizing for the purpose of making cash savings. We believe that the effect of the Board's recommendations at the Scout posts visited, followed by the ration changes inaugurated by the division commander and by General Orders, No. 24, has been to diminish the quantity of rice consumed by Scout companies

[7] Table IV, except for the year 1910, is taken from the reports of the Surgeon-General of the Army. Table V is compiled from records in the office of the Chief Surgeon, Philippines Division. The discrepancy between the total admissions in the two tables is due to the fact that in the chief surgeon's record a new admission is recorded if a patient is transferred from one hospital to another, whereas in the Surgeon-General's report one admission is recorded for such a case. The admissions (50) for 1910 should really be compared with the chief surgeon's figures for 1908 and 1909 (624 and 604, respectively). This would make the showing even more favorable than is given in the text. Fractionally it means that the admissions for 1910 were less than one-twelfth of the average for the two preceding years.

and to increase the amount of meat, beans (mongos) and other components used. The harmful influences attributed to polished rice are believed by us to be due not to the presence of any injurious element in such rice, but simply to the absence from it of some substance necessary for proper nutrition. Hence, it becomes evident that a diminution of the quantity of rice consumed and a substitution therefor of suitable articles of food might produce the same results as would be obtained from the use of an undiminished quantity of rice in which the necessary nutritive substance was present in proper amounts. Therefore, favorable results following the carrying out of our recommendations would by no means be in opposition to the polished-rice theory of beriberi even when the good results appeared before the undermilled rice went into use.

UNDERMILLED RICE NOT THE CAUSE OF DECREASE IN BERIBERI ADMISSIONS.

It is obvious on examining Tables III, V, and VI *that undermilled rice could have had nothing to do with the great decrease in beriberi admissions which occurred prior to August 1, 1910,* and it probably could have had nothing to do with the low rate in August. Undermilled rice *may have contributed a share* to the continuance of the good results in September, October, November and December.

INFLUENCE OF MONGOS, CAMOTES, AND GINGER ROOT ON DECREASE OF BERIBERI.

A study of Tables III, V, and VI (together with the remarks above Table III) will show that the marked decrease in the beriberi rate for April and May and probably for June could not have been due to the mongos, camotes, and ginger root added to the ration by General Orders, No. 24. At this writing there are no figures to show how extensively mongos and camotes were used as a result of the division commander's letter of November 3, 1909; so that a beneficial influence from mongos and camotes prior to May, 1910, can not be excluded. For reasons which will not be entered into here the Board does not consider that there is any special virtue in mongos and camotes as compared with beans and Irish potatoes which would enable them to prevent beriberi. There is little doubt that the mongo is a good beriberi-preventing vegetable, but it is not any better than the bean recommended by this Board on September 30, 1910. We do not consider either camotes or potatoes of much value in preventing the disease. The influence of ginger root can be eliminated because of its date of issue as well as for other reasons.

THE REAL CAUSE OF THE ERADICATION OF BERIBERI FROM THE SCOUTS.

From the above discussion the Board concludes that the important beriberi preventing factor in the new Filipino ration prescribed by General Orders, No. 24, was neither mongo, nor camote, nor ginger root, nor undermilled rice, *per se*, but was *the reduction in the quantity of rice consumed and the substitution, in lieu of the rice taken away, of a*

legumen, which in this case was mongos but which might equally well have been beans as recommended by the Board on September 20, 1910.

The following table will show graphically the periods over which there was active each one of the five new factors, (*a*) undermilled rice, (*b*) camotes, (*c*) mongos, (*d*) ginger root, and (*e*) reduction of rice to 16 ounces and addition of a legumen. The solid part of the lines indicates the period during which the influence was general and the dotted part the period during which the influence was beginning and did not affect all the Scout organizations.

TABLE VI.—*Beriberi admissions by months, calendar year 1910, and influences acting thereon.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Admissions	19	8	12	3	4	1	0	2	0	0	0	10
No. 2 rice (*a*)							......	——	——	——	——	——
Camotes (*b*)					..	......	——	——	——	——	——	——
Mongos (*c*)					..	......	——	——	——	——	——	——
Ginger root (*d*)					..	......	——	——	——	——	——	——
Reduction and legume (*e*)	..——	——	——	——	——	——	——	——	——	——	——	——

It is obvious that factor (*e*), viz, reduction in the amount of rice and addition of a legumen, is the *only one* which has been operative during the whole period of marked decrease in beriberi admissions.

It might be argued, by those favoring the nitrogen starvation theory, that the decrease in beriberi in 1910 was due to an increase in the amount of meat consumed by the Scouts as a result of the letter of the division commander which directed the making of savings as largely as possible on potatoes, onions and coffee. We do not think that an increased meat consumption has been an important factor for the following reasons: (*a*) The Scout did not as a rule make large savings on his meat component and (*b*) the meat allowance is so great (12 ounces) that the Scouts could make considerable savings thereon and still have an amount larger than is furnished the soldier of many of the European armies, the French allowing 10.6 ounces of meat, the Russian 7.75 ounces and the Austrian 6.7 ounces. In considering these figures it should be borne in mind that the average weight of a Filipino is about four-fifths that of a European or American.

IV. BEARING ON BERIBERI RATE OF FACTORS OTHER THAN DIETETIC.

During the year 1910 we are aware of no changes in the sanitary conditions among the Scouts, other than dietetic, which could account for the lowered incidence of beriberi. There has been no marked decrease during 1910 in the admission rate for other diseases. The

average monthly admissions for all diseases was 420.5 in 1908, 393.9 in 1909 and 341.5 in 1910. Since beriberi was causing an average monthly admission of over 50 in 1908 and 1909, while the average was only 4 in 1910, it is evident that the average monthly admissions for all causes other than beriberi was not materially lower in 1910 than it was in 1909.

That the reduction in beriberi among the Scouts in 1910 is not coincident with a corresponding lessening of beriberi cases in the general population in the Philippines may be inferred from the following table of death rates which was furnished us through the courtesy of the officials of the Bureau of Health:

TABLE VII.—*Deaths from beriberi.*

Fiscal year.	In Manila.	In 22 provinces (population about 5,000,000).	Total.
1906	406	2,228	2,634
1907	403	1,377	1,777
1908	492	1,180	1,672
1909	924	1,765	2,689
1910	1,002	1,395	2,397
1911 (first half)	911	([a])	----------

[a] Not obtainable.

It should be noted that the rates in Tables VII are for *fiscal* years while those in Tables IV and V are for calendar years. Also that the rates for Manila, 1911, are only for *half* a fiscal year and correspond to the calendar period of June to December, 1910, a period when the admission rate for the Scouts was practically *nil.* We do not attach much absolute importance to the figures in Table VII because the death rates for the general population of the Philippines, even in Manila, are notoriously unreliable for beriberi as well as for other diseases. We do feel, however, that the rates are, relatively, as reliable for 1910 as for the few years preceding and that therefore any extraordinary reduction in the incidence of beriberi in 1910 would have been mirrored in these figures which show a decided increase rather than a decrease in the death rate for the calendar year 1910 in Manila.

The number of cases of beriberi among the Philippine (native) Constabulary, furnished through the courtesy of Major S. C. Guerney, are as follows: 1908, 52 cases; 1909, 193 cases; 1910 (11 months), 61 cases.

The occurrence of cases by months for 1910 is shown in Table VIII and compared with admissions for same months among the Scouts.

TABLE VIII.—*Comparison of admissions for beriberi among Scouts and Constabulary.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Scouts	19	8	12	3	4	1	0	2	0	0	0	1
Constabulary	7	14	1	1	7	7	9	4	3	2	6	(?)

The Constabulary consists of approximately 4,000 enlisted men, widely scattered throughout the Archipelago. For some years their beriberi rate has been much less than that for the Scouts, this difference probably being due to the fact that they are differently rationed. The admission rate for 1910 is only one-third that for 1909, but is higher than for 1908. On looking at Table VIII it is obvious that there was no such falling off in the beriberi admission rate among the Constabulary for the last half of 1910 as was seen among the Scouts.

It must be admitted that the very high Scout death rate (2.17 per 1,000) and discharge rate (5.96 per 1,000) for beriberi in the year 1909 may have been to some extent responsible for a low admission rate in 1910 because these two processes, death and discharge for disability, doubtless eliminated many old chronic cases which had kept returning on sick report after apparently having been cured. We do not think, however, that this was the important feature in lowering the admission rate for 1910.

V. SUMMARY AND CONCLUSIONS.

THE BOARD STILL ADHERES TO THE POLISHED-RICE THEORY OF BERIBERI PRODUCTION.

The real factors in the eradication of beriberi from the Scout organizations have been a reduction in the amount of rice consumed and the addition of a legumen. The result was accomplished without the use of undermilled rice. The Board still favors the polished-rice theory of beriberi production as being the one best supported at the present time by experimental evidence and practical experience in many localities. It is considered that the good results with the Scouts help to support the theory. The Board feels that the adoption of an undermilled grain for the Philippine Scouts will allow rice to be used more freely by these soldiers with less risk of beriberi than would be the case if the polished article were supplied to them. This is a very important point because, as a result of racial taste and custom, a certain number of natives will attempt to subsist mainly on rice no matter how extensive, varied or well balanced may be the diet supplied to them by the subsistence department. If polished rice is being issued to the troops, those men will be

the first to develop beriberi whenever for any reason a period of unfavorable dietetic administration supervenes.

Since rice is the natural and economical diet for the oriental native it follows that the free use of undermilled rice is likely to work in the direction of both efficiency and economy.

CONCLUSIONS.

(1) Beriberi has disappeared from the Philippine (native) Scout organizations during the last half of the year 1910.

(2) There have been no sanitary improvements to account for this except the changes in diet and there has been no corresponding decrease in the admission rate for diseases other than beriberi.

(3) There was no corresponding decrease in the incidence of beriberi in the general Filipino population or in the Philippine (native) Constabulary.

(4) The decrease in admissions for beriberi among the Scouts was clearly marked for four months before the use of undermilled rice began.

(5) The decrease in admissions was well under way before the mongos, camotes and ginger root of the new ration began to be issued.

(6) The decrease in the admissions for beriberi was due either to unknown causes acting coincidently with a reduction in the amount of rice used and the addition of a legumen, or was due directly to these dietetic changes. As no other reduction in admissions even approaching that of 1910 has occurred since the organization of the Scouts in 1901 we do not believe that the present decrease is due to coincidence.

(7) The facts do not oppose the polished-rice theory of beriberi production. On the contrary, we believe that they support it.

A CASE OF DYSENTERY CAUSED BY BALANTIDIUM COLI WITH COINCIDENT FILARIAL INFARCTION OF THE SPLEEN.[1]

By Fred B. Bowman.

(*From the Biological Laboratory, Bureau of Science, Manila, P. I.*)

The clinical history and protocol of the following case illustrate very well the very serious nature of infection with *Balantidium coli*. In a previous paper[2] I reported two cases and there is a great similarity between one of these and that about to be reported, both in the clinical history and the findings at autopsy.

The case was found during the routine examination of fæces at Bilibid Prison, Manila, and was immediately placed under observation in the hospital. The patient, when admitted to the hospital, complained only of mild diarrhœa. He rapidly recovered without any medicinal treatment, the parasites disappeared from the stool, and he was returned to duty. One month later (August 17) the patient was again admitted to the hospital, complaining of pain in the chest, cough, bloody diarrhœa, and fever. Temperature on entrance, 40°. I was unable to follow the case closely for a few days, but the temperature gradually became lower and he seemed to be improving until August 26, when his temperature again began to rise, the pulse became weak and respiration more rapid. On August 30 I examined him and made the following notes:

The patient is a male Filipino, age 40, with no history of previous illness except occasional attacks of diarrhœa during the past year. He appears to be in almost a collapsed condition and is roused with difficulty and then can not answer questions.

He is hiccoughing regularly and coughs occasionally, bringing up large amounts of greenish-white material, greenish flakes, and some blood-stained mucus.

The tongue is heavily coated and the breath foul. The eyes are protruded and the pupils dilated. The face is distorted as if from great pain.

There is some pulsation of the vessels of the neck. The pulse is weak and

[1] Read at the Eighth Annual Meeting of the Philippine Islands Medical Association, Manila, February 24, 1911.

[2] *This Journal, Sec. B.* (1909), 4, 417.

thready, although regular. The apical impulse is normally situated and the heart is not enlarged. Pulse rate, 95 per minute.

Breathing is rapid; vocal fremitus somewhat intensified in the base of the left lung, and this area is also somewhat dull on percussion. In the bases of both lungs and up toward the axillæ, coarse râles may be heard and also an occasional friction rub.

The spleen can not be palpated. The liver is normal in size. The abdomen is slightly prominent and this is particularly apparent in the left flank, where there is distinct bulging. The entire abdomen is tender on palpation, but this is particularly noticeable in the colon area on both sides and in the epigastrium. There is great general muscular weakness. The patient lies for the greater part of the time with the legs flexed.

The bowels move frequently and the motion is accompanied by tenesmus. The stool is very thin and sanguineous. During the past week there has been much blood present, more than at any time during the course of the illness.

Microscopic examination of the fæces shows many balantidia present (30 or 40 in one cover-glass specimen) also much blood and mucus.

Blood examination.—The blood is very pale and coagulates slowly. Hæmoglobin, 70 per cent; white blood cells, 4,000. Differential counts show no eosinophilia to be present and the blood picture is practically normal. *Urine,* some albumin and a few casts present.

August 31: The patient is much weaker and can not be roused. Heart very feeble. He is still hiccoughing. The abdomen is very tender, but no other signs of peritonitis are observed.

The patient died on September 1 at 4.45 a. m. Many methods of treatment were used without any definite effect being produced. Enemata of quinine, silver nitrate and thymol were given, also ipecac by mouth in large doses.

Protozoa other than *Balantidium coli* were never found during the course of the disease, although the fæces were examined daily. The autopsy was performed by me four hours after death.

The protocol follows:

Autopsy.—The body is that of a well-nourished Filipino. Rigor mortis is present. The pupils are equal and dilated. The superficial glands are not palpable. There is a fair amount of subcutaneous fat and the muscles of the abdomen and chest are fairly well developed and of good color.

On opening the thoracic cavity the sternum is raised with great difficulty because of fibrous adhesions. The *pericardial cavity* contains a fair amount of straw-colored fluid. Some fibrous bands may be seen between the visceral and parietal pericardium toward the apex of the heart. A few "milky patches" occur on the anterior portion of the heart, some having tags of tissue attached to them.

A layer of yellow fat surrounds *the heart.* The coronary arteries are somewhat hard and tortuous. On cut section, the heart muscle is of good color. The wall of the right ventricle is thickened. The valves of the heart apparently are normal with the exception of the mitral leaves, which are thickened and apparently incompetent.

The *aorta* is thickened near the ventricle and is only slightly elastic.

The lungs, both right and left, are firmly attached throughout to the chest wall by fibrous adhesions and can only be removed by rupturing the lung tissue.

Both lungs are crepitant in parts, less so in the apices than in the bases. On

cut section the lung appears mottled with dark red areas surrounding the bronchioles and from these areas bloody serum may be expressed and from the bronchioles a creamy fluid. No nodules or calcified areas can be found. The bronchial glands are not enlarged.

The *peritoneum* is distinctly thickened and is not glistening. Scattered over the surface are grayish-white patches.

The *spleen* is normal in size. The capsule is thickened and fibrous bands of connective tissue attach the spleen to the colon and posteriorly to the abdominal wall. On passing the hand over the spleen surface numerous nodules may be felt from 1 to 3 centimeters in diameter. These project somewhat from the surface. On section, the pulp is friable and congested. The Malpighian bodies are indistinct. The nodular areas extend into the pulp for a distance approximately the same as their diameter on the surface. When a nodule is sectioned the tissue bulges out and is bright red in color. Fibrous bands extend in different directions through the spleen pulp.

The *mesentery* is greatly thickened. The mesenteric glands are not enlarged but many of them show some injection.

The *liver* is somewhat enlarged and firmly attached to the diaphragm above by fibrous bands, and is adherent below to the gut. Cross section shows a loss of normal structure with areas of congestion scattered here and there.

The *gall bladder* is normal and the duct is patent.

The *pancreas* appears somewhat smaller than normal and is firmly adherent to the adjacent viscera. The capsules of the *kidneys* strip with difficulty. The striations are irregular and the kidney substance pale.

The *stomach* appears to be normal, also the duodenum and small intestine. The *colon* (see Pl. I) in its entirety is one mass of ulcers from which hang tags of necrotic tissue. The description given in the previous report[8] exactly covers the condition here present. The ulceration in this case is rather more general than in the one reported before, but perforation has not taken place. The ulceration is much more severe near the rectum, it gradually becomes less so toward the cæcum and in general appears very much like an amœbic infection.

The urinary bladder apparently is normal. Scrapings from the intestinal ulcers show numerous *Balantidium coli* but no other animal organisms; those from the nodules in the spleen, from the wall of the urinary bladder, and from areas of pleuritis were negative.

Anatomic diagnosis.—Broncho-pneumonia; chronic adhesive pleuritis; chronic adhesive pericarditis; splenic infarction; chronic nephritis; chronic adhesive peritonitis; chronic ulcerative colitis (*Balantidium coli*); perihepatitis; mitral endocarditis; arteriosclerosis.

Histologic examination.—The histologic examination of all the tissues will not be given, special reference being made only to those organs which were found interesting pathologically.

Spleen.—Appears normal in parts, but other areas show severe hæmorrhage, the sinuses being crowded with blood cells and the normal splenic structure indistinct. Filarial embryos may be seen here and there lying close together in the sinuses in groups of two or three. (See Pl. II, fig. 3.) These are much more numerous near the center of the hæmorrhagic areas, gradually decreasing in numbers until the normal spleen tissue is reached.

Colon.—Examination of one of the ulcers of the colon shows some balantidia

[8] *Loc. cit.*

lying in the necrotic tissue and a few in the mucosa, the largest number being in the submucosa. Here they are seen in nests in the blood vessels and in the surrounding tissue; and they again may be demonstrated in sections cut through apparently normal portions of the gut at some distance from any ulcer.

SUMMARY.

During the past three years I have seen ten cases of infection with *Balantidium coli,* although during the past eight months balantidia have been found in the fæces of 16 patients in Bilibid Prison hospital. Two of the ten cases terminated fatally, but the others have had no symptoms other than an occasional diarrhœa. Even in the severe infections, the diarrhœa was more or less intermittent in character, the parasites being found in the fæces only during these attacks. This phenomenon might be explained in the following manner: The organisms, moving along in the submucosa, become so numerous as sometimes to form "nests" from which low inflammations develop, and which, proceeding to ulceration, cause erosion of the mucosa and set free the balantidia. (See Pl. II, fig. 1.) At this time the organisms are found in the fæces. In some areas the blood-vessels appear practically to be occluded by the number of balantidia present and this fact in itself is sufficient to initiate an inflammatory process by lowering the tissue resistance.

The possibility that the parasite may carry bacteria and thus cause an inflammatory reaction has been suggested. I have invariably found that the cellular infiltration which is present around the organisms situated beneath the unbroken mucosa practically consists of lymphoid cells and a few eosinophiles (Pl. II, figs. 1 and 2), very few polymorphonuclear leucocytes being present. This fact in itself seems to show conclusively that the primary inflammation is not caused by bacteria. However, the necrotic material covering the ulcers is composed largely of leucocytes and there is no doubt that the terminal, acute ulceration begun by *Balantidium coli* in the underlying tissue is due to a great extent to the entrance of intestinal bacteria.

The manner of primary invasion is not determined. It has not been established whether the mucosa must be injured before the parasites can enter or whether they in themselves are capable of piercing the uninjured mucosa. A third possibility is that they liberate a cytolytic ferment which causes the injury. However, once an entrance is gained, multiplication rapidly takes place and it is only a matter of time until the entire colon may be infected.

I have examined many preparations, both fresh and stained and fixed in the tissue, but have never seen any distinct evidence of conjugation taking place between two organisms. The balantidia may be seen in groups and in pairs closely attached, but showing no nuclear cytoplastic

changes. It often has been observed that flagellates and ciliates tend to group themselves together in fresh specimens. This grouping apparently has no relation to conjugation and probably is due to mechanical action alone.

We know that the organisms multiply by division. In almost any field where they are numerous, either in stained sections from colonic ulcers or in stained fæces, partial or complete division of the nucleus may be seen. Balantidia with central constriction may be found in fresh specimens as may also many very small, elongated young forms which seem to be the result of this division. As yet we have had no success as to cultivation. I have observed balantidia alive forty-eight hours after inoculation on Musgrave and Clegg's amœba medium, and Walker in this laboratory has noted life for one week on the same medium, but the balantidia apparently had not reproduced and those which remained alive were left from the original individuals which had been inoculated.

In view of the fact that Brooks has reported an epidemic of dysentery due to *Balantidium coli* among the apes of the New York Zoölogical Park [4] and Noc F.[5] a natural infection in a monkey (*Macacus cynomolgus* Geoff.) we would expect to be able to produce the disease experimentally in monkeys.

I have attempted to infect monkeys, but have been unsuccessful. Fresh fæces from a case of severe infection were many times injected into the rectum and the monkey suspended by his lower extremities in order that none of the material could be evacuated. Frequent examinations showed no balantidia present.

A colotomy was also performed on another monkey and 20 cubic centimeters of infected fæces were injected into the colon on two occasions. The organism never appeared in the fæces.

Some tissue from an ulcer removed at the autopsy reported in this paper was inserted beneath the mucosa of the colon of a monkey and well sutured in. This operation was done in the hope that in the tissue of the ulcer, resting or encysted forms might occur which would be more resistent to manipulation and conditions incidental to the changing of the host, and which might develop and infect the animal. No balantidia were ever found in the fæces, nor were any symptoms of dysentery noted.

I have never seen anything which could possibly be construed as an encysted *Balantidium coli* in fresh fæces, although many round, vacuolated, nonmotile organisms were found in old specimens. In a short time these organisms became flattened and irregular, and extruded granular degenerative material from the periostome.

[4] *N. Y. Aniv. Bull. Med. Sci.* (1902), January.
[5] *Compt. rend. Soc. biol.* (1908), 64.

CONCLUSIONS.

1. *Balantidium coli* is a parasite and, although not so common an infecting agent as the amœba, in individual cases it is more serious in its effects. The prognosis in early cases is bad and in late ones practically hopeless.

2. A search through the literature fails to show a report of splenic infarction due to filarial embryos in an uncomplicated infection. Infarcts of the spleen with numerous filarial embryos present have been reported in a case of Bubonic plague.[6]

Infarctions occur frequently in plague and it is possible that the embryo filariæ in the case cited above were only present coincidently and not the primary cause of the infarction.

[6] Über die Beulenpest in Bombay im Jahre 1897. Albrecht und Ghon: II. Wissenschaftlicher Theil des Berichtes. B. (1898), 237.

ILLUSTRATIONS.

PLATE I.

Photograph of colon, showing severe ulceration caused by *Balantidium coli.*

PLATE II.

FIG. 1. Section through apparently normal colon, which microscopically shows two balantidia lying in the submucosa causing cell infiltration which will probably proceed to ulceration of the mucosa.

2. Two balantidia lying in the submucosa. Practically no cell reaction present.

3. Filarial embryos in spleen pulp, causing infarction.

PLATE I.

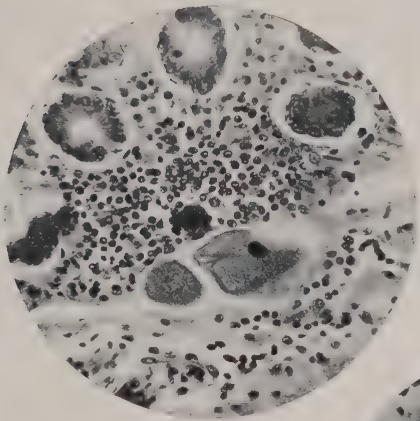


FIG. 1.

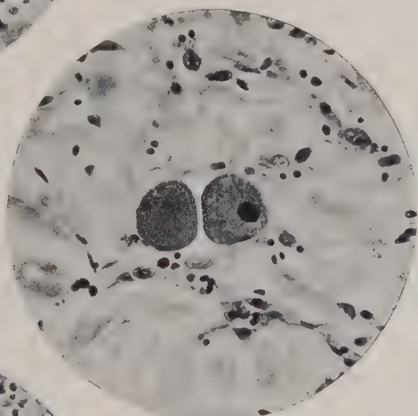


FIG. 2.

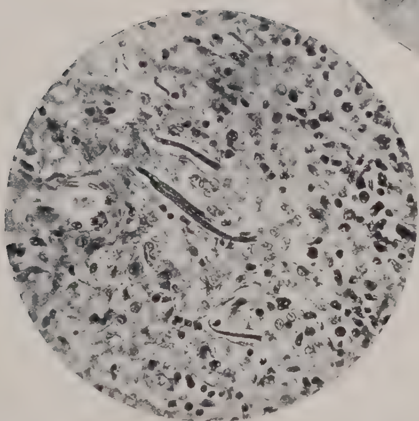


FIG. 3.

PLATE II.

SOME OBSERVATIONS ON SO-CALLED FLAGELLATES, CILIATES, AND OTHER PROTOZOA ENCOUNTERED IN WATER AND IN HUMAN STOOLS.

(PRELIMINARY REPORT.)

By E. H. RUEDIGER.

(*From the Serum Section, Biological Laboratory, Bureau of Science, Manila, P. I.*)

During routine examinations of diarrhœal stools made a short time ago among members of what may be considered a camping party, flagellates (species undetermined) were encountered frequently, ciliates (species not identified) occasionally, and on two occasions one other protozoön which will briefly be described later on in this paper.

Whenever there is an outbreak of diarrhœa, especially in a camp, the drinking water naturally is one of the first things to receive attention. The drinking water at the place in question was distilled and obtained from a distilling plant about 2 or 3 kilometers from the camp. The water was stored at the distilling plant in a closed, practically air-tight iron tank, and it was delivered in a closed iron tank every morning; it was stored at the camp in large galvanized-iron cans with loose covers, from which the coolers were filled for drinking purposes. In transferring the water from the receiving cans to the coolers a milk pitcher or similar vessel usually was employed and in so doing the hand frequently came in contact with the water, thus making an avenue for contamination; and other chances for infection were numerous. Samples of water from the various places, the distilling plant, the water wagon, the receiving cans, and the water coolers at the camp, were examined as follows.

1. *May 16.*—A sample of 1,000 cubic centimeters of distilled water from the storage tank at the distilling plant and one of the same amount from the water wagon were put into a sterile flask, about 20 cubic centimeters of sterile, melted nutrient agar was added and the whole incubated for three days. Result of microscopic examinations made May 19: No amœbæ, no ciliates, no flagellates.

2. *May 16.*—A sample of 1,000 cubic centimeters of water from the receiving cans at the camp was put into a sterile flask, and the same procedure followed.

Result of microscopic examination made May 19: No amœbæ, no ciliates, but swarming with flagellates.

3. *May 16.*—A sample of 1,000 cubic centimeters of water from the water coolers at the camp was put into a sterile flask, and the method outlined above was followed out. Result of microscopic examination May 19: No amœbæ, no flagellates, but a large number of ciliates were present.

The results obtained with samples 2 and 3 at once attracted my attention. Water from the coolers which previously had been in the receiving cans yielded ciliates and no flagellates, while the water from the receiving cans yielded flagellates, but no ciliates. The appearance of ciliates in water from the coolers is explained readily by assuming that the ciliates were in the coolers when the latter were filled, or that they entered that water in some other manner while the receiving cans had remained free from them. However, the disappearance of the flagellates which were present in the water from the receiving cans and absent from the water in the coolers was not so readily explained and became the subject of some study.

EXPERIMENT 1.

May 21.—About 10 cubic centimeters of sample 2, containing a large number of flagellates, was put into a sterile test tube and about 10 cubic centimeters of sample 4, containing a large number of ciliates, was added. On microscopic examination many flagellates and ciliates were found. On May 22 microscopic examination showed a large number of ciliates, but no flagellates. On May 23 microscopic examination showed many ciliates, but no flagellates.

EXPERIMENT 2.

May 23.—A clean bottle of 250 cubic centimeters capacity was nearly filled with water, and about 10 cubic centimeters of melted nutrient agar was added and sterilized. After cooling, a few cubic centimeters of sample 3, rich in flagellates, and a few cubic centimeters of sample 4, rich in ciliates, were added. Microscopic examination made immediately showed a small number of flagellates and a small number of ciliates.

May 24.—On microscopic examination, a moderate number of flagellates and a moderate number of ciliates were found.

May 25.—Microscopic examination revealed ciliates but no flagellates.

May 26.—Many ciliates, but no flagellates.

May 27.—A large number of ciliates, but no flagellates.

May 28.—Many ciliates but no flagellates.

EXPERIMENT 3.

May 30.—One large platinum loopful of water rich in flagellates was put into the cavity of a hollowed microscopic slide, three loopfuls of water rich in ciliates were added, and a cover glass placed over the cavity. Microscopic examination made immediately after mixing the two showed a large number of ciliates and a moderate number of flagellates. On examining the mixture two hours later, ciliates only were found, all flagellates having disappeared.

May 31.—Microscopic examination made about twenty-four hours after mixing the two showed all ciliates encysted; flagellates were not seen.

EXPERIMENT 4.

May 31.—One large platinum loopful of a culture containing many flagellates was put into the cavity of a hollowed microscopic slide, three loopfuls of a culture containing many ciliates were added and a cover glass placed over the cavity. On examination immediately after mixing, both the ciliates and the flagellates seemed very lively and appeared to attack one another. The motions of the flagellates soon became sluggish, and after about ten minutes ceased entirely. One ciliate which appeared to be about forty times as large as a flagellate, guarded a group of 20 flagellates crowded close together and entirely motionless. The ciliate continually circled around the group of flagellates, and as soon as one of the latter started to move he was attacked by the former which appeared to whip him with its cilia, a few beats of which seemed to render the flagellate motionless. Unfortunately, the observation had to be interrupted and when I returned an hour later all flagellates had disappeared, but the ciliates were actively motile. I was not able to determine in just what manner the flagellates were disposed of, whether devoured by the ciliates or destroyed by lysis. Ciliates, after having disposed of flagellates, contained many large granules which in size and shape corresponded to flagellates and which disappeared within twenty-four hours. Ciliates grown in the absence of flagellates showed no such large granules, on the contrary the organisms were finely granular.

EXPERIMENT 5.

June 3.—One large platinum loopful of a culture of ciliates was put into the cavity of a hollowed microscopic slide, three loopfuls of a culture of flagellates were added and the cavity covered with a cover glass. On examining the mixture immediately after preparation a large number of flagellates and a small number of ciliates were seen. Both were actively motile and appeared to attack one another.

Microscopic examination made an hour later showed the flagellates actively motile and the ciliates sluggishly moving. Microscopic examination ten hours after the specimen was prepared showed the flagellates actively motile and the ciliates encysted.

June 4.—Microscopic examination showed the flagellates motile and the ciliates encysted.

EXPERIMENT 6.

June 4.—About 20 cubic centimeters of water were put into a test tube, a small quantity of nutrient agar was added and the mixture then sterilized. After cooling, 1 cubic centimeter of a culture of ciliates and about 10 cubic centimeters of water rich in flagellates were added. Immediately after having been mixed, a moderate number of actively motile flagellates and a small number of actively motile ciliates were noticed under the microscope.

June 5.—Microscopic examination showed a large number of flagellates and a small number of sluggishly motile ciliates.

June 6.—The flagellates were actively motile and all ciliates were encysted.

June 7.—Microscopic examination showed a large number of motile flagellates and a small number of encysted ciliates.

MULTIPLICATION OF THE CILIATES.

What appears to be the adult ciliate is pear-shaped or egg-shaped, the cilia (their actual number was not determined) are situated at the narrower extremity, and the organism moves in that direction. One nucleus is usually present. The organism increases in size (means for

taking measurements were not at hand), the nucleus divides to form two daughter nuclei, one of which moves toward the narrower, the other toward the broad extremity, the cilia disappear, motility is lost, the organism assumes an oval shape and a transverse constriction appears at the middle. The constriction becomes more and more pronounced, a circle of cilia appears at the proximal end of each daughter cell, the neck continues to narrow, the cilia become motile; finally, division of the cells is complete and each daughter cell, nearly spherical in shape, moves slowly away. As the organism increases in size it assumes a pear-like shape.

Nuclear changes are frequent throughout the process of cell division. The nucleus, large and distinct, suddenly disappears from view, to reappear in a slightly different part of the cell after a few seconds. At times two distinct nuclei are present in a daughter cell, these move toward each other and fuse to form one.

Multiplication of the cells was not observed in the flagellates.

CULTIVATION OF THE CILIATES.

The following cultural tests were made in conjunction with bacteria that were present in the water or in the stools. Attempts to grow the ciliates free from bacteria were not successful.

Nutrient broth.—When inoculated with material containing ciliates and bacteria, it became heavily clouded and microscopic examination revealed motile ciliates and bacteria.

Agar-agar.—A heavy, translucent, whitish, moist streak appeared along the line of inoculation. Microscopic examination showed a large number of motile ciliates and bacteria.

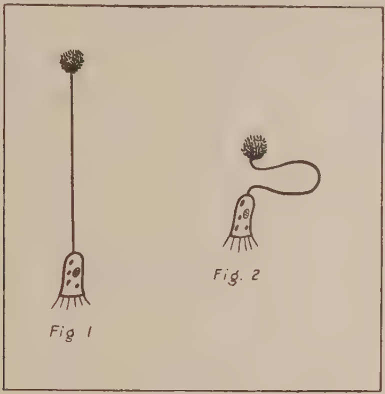
Lactose-litmus-agar.—A heavy, translucent, whitish, moist growth appeared along the line of inoculation. Microscopic examination showed many motile ciliates and bacteria.

Attempts to cultivate the flagellates on solid media were unsuccessful.

THE OTHER PROTOZOÖN PRESENT IN THE WATER.

The other organism mentioned in the beginning of this paper was twice cultivated from diarrhœal stools and was always found in cultures made of sewage and from a spring which, during rain, received the surface drainage of several hundred meters of the wagon road. The organism, when seen in cultures made after the method employed in examining water for amœbæ, is bell-shaped. (See fig. 1.) A hair-like line, about five times the length of the organism, arising from the part which corresponds to the top of the bell, extends to a clump of dirt, a cluster of algæ, or any substantial anchorage, where it appears to be fastened. The part which corresponds to the open end of the bell is surrounded by a circle of cilia which are actively motile and set up a whirling motion of

the water surrounding the cell. Apparently there is slight suction into the broad extremity of the cell, which appears to be closed by a membrane. As dirt and bacteria become entangled in the cilia and appear to be sucked against the membrane, the motility of the former ceases and with a quick



jerk the organism assumes the position shown in figure 2. The jerk seems to have freed the cilia and the membrane from dirt, the organism slowly moves back to its former position and the cilia resume their motility.

CONCLUSIONS.

1. Flagellates and ciliates seem to antagonize each other. The ciliates, when in sufficient numbers, destroy the flagellates. If the flagellates sufficiently outnumber the ciliates, conditions then are unfavorable for the ciliates and they encyst.

2. The ciliates can without difficulty be cultivated in symbiosis with bacteria on liquid and on solid culture media. Attempts to secure the ciliates in pure culture have failed thus far.

3. The ciliates multiply by transverse division of the cell.

4. Attempts to cultivate the flagellates on solid media were not successful.

ILLUSTRATIONS.

TEXT FIGURES.

REVIEW.

The Treatment of Disease. A Manual of Practical Medicine. By Reynold Webb Wilcox, M. A., M. D., LL. D. Cloth. Pp. VIII + 1023. Philadelphia: P. Blakiston's Son & Co., 1911.

This "manual" of over 1,000 pages lacks both the conciseness of a handbook and the fullness and completeness of a system of medicine. The author has attempted to cover too much ground and to discuss diseases beyond his personal knowledge and experience. The value to a general practitioner in the United States of the sections on "Nasha fever," "Japanese river fever," "verruga," etc., seems questionable, while to a practitioner in the Tropics a more complete treatment of these subjects is necessary.

In the nomenclature of diseases the author too often falls into the unfortunate error of referring to the diseases according to the names of the early describers of the conditions, rather than according to their true nomenclature. Thus he describes Brill's Disease, Weil's Disease, Duke's Disease, Friedrich's Disease, Gerlier's Disease, Milroy's Disease, etc.

The use of "Anchylostomiasis" rather than "agchylostomiasis" is not in accordance with the latest revision of the nomenclature of tropical diseases. The arrangement of the subject matter seems logical and clear for the most part.

Of the modernity and accuracy of the subject matter little need be said after noting that typhoid fever, which is now recognized as primarily a septicæmia to be detected by blood cultures and secondarily as an infection of the intestinal lymph nodes, is to be treated, according to the author, with intestinal disinfectants, etc., and then "If the disease is not inhibited the first week of the exhibition of these salts, the problem is complicated by the fact that the infection has become systemic;" and again, in the section on "Beriberi," by noting the statement that "It is, however, quite likely that rice is really the medium through which the germ of this disease operates, because if cured be substituted for uncured rice the disease disappears."

The advantages of this textbook as compared with the more reliable and readable "Practice of Medicine," by Osler, are so few as to make its field of usefulness limited.

D. G.